

8. RI/BRA SUMMARY AND CONCLUSIONS

The following sections summarize the nature and extent of contamination and the human health and ecological risk assessments. Sections 1 through 7 of this document form the basis for the conclusions presented.

8.1 Contamination Nature and Extent Summary

Fifty-two potential release sites identified in the FFA/CO were evaluated as part of this BRA. Fourteen of these sites were retained following a contamination nature and extent evaluation and contaminant screening (Section 4) and for quantitative evaluation in the baseline risk assessment (Section 6). The nature and extent of contamination at all sites retained for evaluation in the BRA is based on data collected during the OU 4-13 field investigation and previous WAG 4 investigations.

8.2 Human Health Risk Evaluation Summary

The human health BRA consisted of two broad phases of analysis; 1) site and contaminant screening that identified release sites and COPCs that could produce adverse human health impacts to workers and potential future residents at WAG 4, and; 2) an exposure route analysis and estimates of human health risk for each COPC. The exposure route analysis includes an exposure assessment, a toxicity assessment, and a risk characterization discussion. The BRA includes an evaluation of human health risks associated with exposure to contaminants through soil ingestion, dermal absorption from soil, fugitive dust inhalation, volatile inhalation, external radiation exposure, groundwater ingestion, ingestion of homegrown produce, dermal absorption of groundwater, and inhalation of water vapors due to indoor water use. Potential risks are assessed on a cumulative basis for the air and groundwater exposure pathways (i.e., estimated risks for these pathways are equivalent for each site evaluated in the BRA).

Tables 8-1 through 8-3 summarize the results of the human health risk assessment with respect to the evaluated exposure routes. Table 8-1 indicates which release sites have calculated risks in excess of $1\text{E-}04$, Table 8-2 indicates which release sites have calculated risks in excess of $1\text{E-}06$, and Table 8-3 indicates which release sites have calculated hazard indices in excess of 1.

The EPA permissible risk range is $1\text{E-}04$ to $1\text{E-}06$ for carcinogens and ≤ 1.0 for noncarcinogens. Sites with potential risks that exceed any of these criteria are retained for further evaluation in the Feasibility Study (Sections 9–12). Six of the 14 sites retained for evaluation in the BRA exceed the EPA permissible risk criteria: CFA-04 Pond, CFA-08 Drainfield, CFA-10 Transformer Yard Oil Spills, CFA-12 French Drain; south drain. CFA-13 Dry Well, and CFA-15 Dry Well.

The exposure routes identified as potentially complete for these sites that have calculated risks above the EPA target risk range at WAG 4 (i.e., potential excess cancer risk exceeds $1\text{E-}04$ to $1\text{E-}06$; target hazard index exceeds 1.0) are ingestion of soil, dermal contact with soil, external radiation exposure, and ingestion of homegrown produce.

The contaminants that are associated with the greatest potential for adverse human health effects at WAG 4 (i.e., potential excess cancer risk exceeds $1\text{E-}04$; hazard index exceeds 1.0) are metals and radionuclides. These contaminants are shown in Table 8-4 according to the exposure scenario (i.e., occupational or residential exposure) in which they are predicted to produce unacceptable risks. These contaminants are considered to be COCs for WAG 4.

Table 8-1. Summary of sites and exposure routes with calculated risks greater than 1E-04.

Site	Occupational Scenario					Residential Scenario								
	Soil			Air		Soil			Air		Groundwater			
	Ingestion of soil	Dermal absorption of soil	External radiation exposure	Inhalation of fugitive dust	Inhalation of volatiles	Ingestion of soil	Dermal absorption of soil	Ingestion of homegrown produce	External radiation exposure	Inhalation of fugitive dust	Inhalation of volatiles	Ingestion of GW	Dermal absorption of GW	Inhalation of vapors from indoor water use
OU 4-02: CFA-13 Dry Well (South of CFA-640)									●					
OU 4-02: CFA-15 Dry Well (CFA-674)									●					
OU 4-05: CFA-04 Pond (CFA-674)														
CFA-17 Fire Department Training Area, bermed/ CFA-47 Fire Station Chemical Disposal														
OU 4-07: CFA-07 French Drain E/S (CFA-633)														
CFA-12 French Drain (2) (CFA-690) (south drain only)									●					
OU 4-08: CFA-08 Drainfield			⊙						●					
OU 4-08: CFA-08 Sewage Plant (CFA-691)														
OU 4-09: CFA-10 Transformer Yard Oil Spills														
CFA-26 CFA-760 Pump Station Fuel Spill														
CFA-42 Tank Farm Pump Station Spills														
CFA-46 Cafeteria Oil Tank Spill (CFA-721)														
OU 4-11: CFA-05 Motor Pond Pool														
OU 4-13: CFA-52 Diesel Fuel UST (CFA-730) at Building CFA-613 Bunkhouse														
○ = Risk greater than 1E-04 for the current occupational exposure scenario. ⊙ = Risk greater than 1E-04 for the current and future occupational exposure scenario. ● = Risk greater than 1E-04 for the future residential exposure scenario.														

Table 8-2. Summary of sites and exposure routes with calculated risks greater than 1E-06.

Site	Occupational Scenario					Residential Scenario								
	Soil			Air		Soil				Air		Groundwater		
	Ingestion of soil	Dermal absorption of soil	External radiation exposure	Inhalation of fugitive dust	Inhalation of volatiles	Ingestion of soil	Dermal absorption of soil	Ingestion of homegrown produce	External radiation exposure	Inhalation of fugitive dust	Inhalation of volatiles	Ingestion of GW	Dermal absorption of GW	Inhalation of vapors from indoor water use
OU 4-02: CFA-13 Dry Well (South of CFA-640)			⊙			●	●	●	●					
OU 4-02: CFA-15 Dry Well (CFA-674)			⊙					●	●					
OU 4-05: CFA-04 Pond (CFA-674)	⊙	⊙	⊙			●	●	●	●					
CFA-17 Fire Department Training Area, bermed/ CFA-47 Fire Station Chemical Disposal														
OU 4-07: CFA-07 French Drain E/S (CFA-633)														
CFA-12 French Drain (2) (CFA-690) [south drain only]						●		●	●					
OU 4-08: CFA-08 Drainfield	⊙	⊙	⊙				●	●	●					
OU 4-08: CFA-08 Sewage Plant (CFA-691)														
OU 4-09: CFA-10 Transformer Yard Oil Spills		⊙												
CFA-26 CFA-760 Pump Station Fuel Spill														
CFA-42 Tank Farm Pump Station Spills														
CFA-46 Cafeteria Oil Tank Spill (CFA-721)														
OU 4-11: CFA-05 Motor Pond Pool														
OU 4-13: CFA-52 Diesel Fuel UST (CFA-730) at Building CFA-613 Bunkhouse														
○ = Risk greater than 1E-06 for the current occupational exposure scenario. ⊙ = Risk greater than 1E-06 for the current and future occupational exposure scenario. ● = Risk greater than 1E-06 for the future residential exposure scenario.														

Table 8-3. Summary of sites and exposure routes with calculated hazard indices greater than 1.

Site	Occupational Scenario					Residential Scenario							
	Soil			Air		Soil				Air		Groundwater	
	Ingestion of soil	Dermal absorption of soil	External radiation exposure	Inhalation of fugitive dust	Inhalation of volatiles	Ingestion of soil	Dermal absorption of soil	Ingestion of homegrown produce	External radiation exposure	Inhalation of fugitive dust	Inhalation of volatiles	Ingestion of GW	Dermal absorption of GW Inhalation of vapors from indoor water use
OU 4-02: CFA-13 Dry Well (South of CFA-640)						●							
OU 4-02: CFA-15 Dry Well (CFA-674)													
OU 4-05: CFA-04 Pond (CFA-674)						●		●					
CFA-17 Fire Department Training Area, bermed/ CFA-47 Fire Station Chemical Disposal													
OU 4-07: CFA-07 French Drain E/S (CFA-633)													
CFA-12 French Drain (2) (CFA-690) [south drain only]													
OU 4-08: CFA-08 Drainfield													
OU 4-08: CFA-08 Sewage Plant (CFA-691)													
OU 4-09: CFA-10 Transformer Yard Oil Spills													
CFA-26 CFA-760 Pump Station Fuel Spill													
CFA-42 Tank Farm Pump Station Spills													
CFA-46 Cafeteria Oil Tank Spill (CFA-721)													
OU 4-11: CFA-05 Motor Pond Pool													
OU 4-13: CFA-52 Diesel Fuel UST (CFA-730) at Building CFA-613 Bunkhouse													
○ = Hazard index greater than 1 for the current occupational exposure scenario. ⊗ = Hazard index greater than 1 for the current and future occupational exposure scenario. ● = Hazard index greater than 1 for the future residential exposure scenario.													

Table 8-4. WAG 4 contaminants of concern.

Exposure Scenario	Radionuclides	Metals	Organic Contaminants	Other
Occupational	Cs-137	Lead	None	None
Residential	Cs-137, Ra-226	Mercury	None	None

The cumulative risk assessment for air and groundwater exposure pathways indicates that potential excess cancer or non-cancer risks do not exceed the EPA permissible risk levels for the occupational and residential exposure scenarios.

8.3 Ecological Risk Evaluation Summary

The objectives of the OU 4-13 WAG ERA were to define the extent of contamination for each site at the WAG level, determine the potential effects from contaminants on environmental receptors, habitats, or special environments, determine the potential effects from contaminants on other ecological receptors at WAG 4, and identify sites and COPCs to be included in the OU 10-04 ERA. The approach used in the WAG ERA is an extension of the screening level ecological risk assessment methodology used at the INEEL (VanHorn, Hampton, and Morris 1995). This methodology uses conservative exposure modeling and input parameters to identify contaminants and sites that may pose a risk to the environment.

The ecological risk assessment is presented in Section 7. All potential release sites identified in the FFA/CO were evaluated for risk to ecological receptors. The retained sites and their associated COPCs were evaluated as discussed in Section 7, using the general approach proposed by EPA (EPA 1994, 1996). As discussed in Section 7.5, the result of this assessment will be utilized as input into the OU 10-04 ERA.

For the purposes of this assessment, HQs greater than the target values (i.e., 1 for nonradiological contaminants, and 0.1 for radionuclides) are indicative of potential adverse effects. Due to the uncertainty in the ERA methods, HQs are used only as an indicator of risk and should not be interpreted as a final indication of actual adverse effects to ecological receptors. Of the sites and COPCs assessed, 11 sites were eliminated as posing no potential risk to ecological receptors (CFA-12, CFA-23, CFA-24, CFA-27, CFA-28, CFA-29, CFA-30, CFA-34, CFA-37, CFA-38, and CFA-42). The results of the assessment indicate risk to ecological receptors at the remaining 16 sites. Table 8-5 summarizes the results of the ERA evaluation by presenting the range of HQs calculated for functional groups potentially present at each site.

A basic assumption of the ERA is that, under a future use scenario, the contamination is present at an abandoned site, which will not be institutionally controlled. In actuality, co-located facilities are currently in use and institutional controls will remain in place until they are decommissioned, at which time they will be reassessed. Since these sites are at an industrial facility that is currently in use, they most likely do not contain desirable or valuable habitat. The absence of habitat, facility activities, and institutional controls will minimize the exposure of ecological receptors to levels which could be considered acceptable.

Additionally, due to the conservative nature of the ERA, an evaluation of the exposure of ecological receptors to some inorganics at or near background concentrations would also be indicative of risk. Therefore, these sites would not be considered in the remedial alternative screening process. The

Table 8-5. Summary of the sites with potential for posing risk to ecological receptors.

Site Number	Site Description and Size (sq. meters)	Contaminant of Potential Concern	Hazard Quotient
CFA-01	Landfill I 4.30E+04	Benzo(a)pyrene	<1 to 2
		Silver	≤1 to 4
CFA-02	Landfill II 7.07E+05	4-methyl-2-pentanone	NA
		Acetone	≤1 to 20
		Benzo(b)fluoranthene	<1 to 1
		Benzo(k)fluoranthene	<1 to 2
		Dibenzofuran	NA
		Lead	≤1 to 700
		Pentachlorophenol	NA
CFA-04	Pond near CFA-674 6.88E+03	Mercury	<1 to 30,000
		Silver	<1 to 6
CFA-05	Motor Pool Pond 7.43E+03	4-methyl-2-pentanone	NA
		Cadmium	≤1 to 10,000
		Copper	≤1 to 100
		Lead	≤1 to 1,000
		Mercury	≤1 to 80
CFA-08	Sewage Plant (CFA-691), Septic Tank (CFA-716), and Drainfield 1.85E+04	Chloromethane	NA
		Mercury	≤1 to 30
		Silver	≤3 to ≤5
CFA-10	Transformer Yard Oil Spills 8.08E+02	Copper	<1 to 70
		Lead	<1 to 3,000
CFA-12	Two French Drains (CFA-690) 1.34E+01	Pentachlorophenol	NA
CFA-13	Dry Well (South of CFA-640)	Copper	≤1 to 20
		Lead	<1 to 33
		Mercury	<1 to 2

Table 8-5. (continued).

Site Number	Site Description and Size (sq. meters)	Contaminant of Potential Concern	Hazard Quotient
		Pyrene	<1 to 2
		Silver	4
CFA-17/47	Fire Department Training Area, bermed and Fire Station Chemical Disposal 1.96E+03	Xylene	≤3 to 10
CFA-21	Fuel Tank at Nevada Circle (S by CFA-629) 7.00E+00	TPH	<1 to 3
CFA-26	CFA-760 Pump Station Fuel Spills 1.12E+02	TPH	≤1 to ≤4
CFA-31	Waste Oil Tank at CFA-754 2.52E+01	TPH	<1 to 1
CFA-40	Returnable Drum Storage (south of CFA-601) 5.40E+02	TPH	<1 to 3
CFA-41	Excess Drum Storage (south of CFA-674) 6.97E+03	TPH	<1 to 20
CFA-43	Lead Storage Area 1.53E+04	Lead	≤1 to 70
CFA-51	Dry Well at north end of CFA-640 1.00E-01	Copper	<1 to 1

Bold text indicates that site was retained after the HQ <10 screen discussed in Section 8.4.

apparent risk from naturally occurring metals will be evaluated specifically during the WAG 10 OU 10-04 ERA.

The ERA determined that risks to ecological receptors exist at 16 sites at WAG 4. Human health risks exceeding allowable levels exist at 5 of these sites and some level of remediation ranging from institutional controls to active remediation will be required. Any remedial alternative that reduces human health risks would be expected to also reduce ecological risks.

8.4 Conclusions

Potential human health risk from past releases at WAG 4 is primarily associated with radiological contamination at CFA-08 Drainfield, and metal contamination at the CFA-04 Pond and CFA-10 yard. The site and type of contaminated media are summarized in Table 8-6.

Six sites (CFA-04, CFA-08, CFA-10, CFA-12, CFA-13 and CFA-15), contain sources of contamination with potential for producing unacceptable human health risk, whoever, will not be evaluated further in the FS because the exposure pathway is not complete. Those risks are primarily associated with radiological contamination at CFA-08, CFA-12, CFA-13, and CFA-15; and metal contamination at CFA-04 and CFA-10. These sites, excluding CFA-15, in addition to eleven other WAG 4 sites (CFA-01, CFA-02, CFA-05, CFA-17/47, CFA-21, CFA-26, CFA-31, CFA-40, CFA-41, CFA-43, and CFA-51), also contain sources of contamination resulting in HQs greater than the target

Table 8-6. Summary of WAG 4 release sites with elevated risk levels to human health and ecological receptors.

Operable Unit	Site	Contaminant of Concern	Receptors		Further Evaluation
			Ecological	Human Health	
4-02	CFA-13	Radium 226		✓	Naturally occurring, not evaluated further in the FS
		Lead	✓		Evaluate in the OU 10-04 RI/FS
		Mercury	✓		Evaluate in the OU 10-04 RI/FS
	CFA-15	Radium-226		✓	Naturally occurring, not evaluated further in the FS
4-04	CFA-41	Lead	✓		Evaluate in the OU 10-04 RI/FS
4-05	CFA-04	Mercury	✓	✓	Evaluate in the FS
	CFA-17/-47	Xylene	✓		Evaluate in the OU 10-04 RI/FS
		Lead	✓		Evaluate in the OU 10-04 RI/FS
4-07	CFA-12	Cesium-137		✓	Exposure pathway not complete due to presence of contaminant in basalt, not evaluated further in the FS
4-08	CFA-08	Pentachlorophenol	✓		Evaluate in the OU 10-04 RI/FS
		Cesium-137		✓	Evaluate in the FS
		Chloromethane	✓		Evaluate in the FS
4-09	CFA-10	Lead	✓	✓	Evaluate in the FS
		Copper	✓		Evaluate in the FS
4-12	CFA-05	Cadmium	✓		Evaluate in the OU 10-04 RI/FS
		Copper	✓		Evaluate in the OU 10-04 RI/FS
		Lead	✓		Evaluate in the OU 10-04 RI/FS
		Mercury	✓		Evaluate in the OU 10-04 RI/FS
		4-methyl-2-pentanone	✓		Evaluate in the OU 10-04 RI/FS
4-12	CFA-02	Lead	✓		Evaluate in the OU 10-04 RI/FS
		4-methyl-2-pentanone	✓		Evaluate in the OU 10-04 RI/FS
		Acetone	✓		Evaluate in the OU 10-04 RI/FS
		Dibenzofuran	✓		Evaluate in the OU 10-04 RI/FS
		Pentachlorophenol	✓		Evaluate in the OU 10-04 RI/FS

value of 1 for ecological receptors. Based on consultation with remedial project managers and agency concurrence, a further screening of sites posing potential ecological risk was performed in which contaminants were eliminated as a concern if the maximum HQ across receptors was less than 10. As a result of the screening, ten of the 16 sites retained after the 10-times background screen for metals remain. These sites include, CFA-02, CFA-04, CFA-05, CFA-08, CFA-10, CFA-12, CFA-13, CFA-17/47, CFA-41, and CFA-43. Contaminants that did not meet this criterion were retained and are shown by bold type in Table 8-5.

8.4.1 OU 4-02: CFA-13 Dry Well

The CFA-13 dry well consisted of a dry well located south of the demolished locomotive repair shop Building CFA-640. The site was excavated during the WAG 4 Miscellaneous Sites 1997 NTCRA, and it was determined that the dry well was sewer clean-out for the demolished Building CFA-640. Excavation was performed to remove the sewer clean-out area and approximately 9 m (30 ft) of the associated piping.

Post-removal data from the 1997 removal action were used to characterize the residual nature and extent of contamination at the site. These data indicate that residual contamination exist in subsurface soils from 0.9 m to 6.1 m (3 to 20 ft) bgs at CFA-13. Polycyclic aromatic hydrocarbons, PCBs, lead, and radionuclides were identified as COPCs in the contaminant screen.

The potential exposure route and associated COC that produce estimated excess cancer risks greater than $1\text{E-}04$ is external radiation exposure to Ra-226 by future residents. Ra-226 is a naturally occurring radionuclide in the U-238 decay chain. It is typically found in all soils at the INEEL at a nominal concentration of 1 pCi/g. The laboratory results will typically report concentrations at approximately 2 pCi/g (Giles 1998). The risk-based concentration for Ra-226 is 0.52 pCi/g, consequently even at background concentrations, Ra-226 will appear to present an unacceptable risk. Concentrations at CFA-13 are at background levels when corrected for instrument detection. In addition, Ra-226 was not disposed to the drywell and therefore should be considered to be a naturally occurring radionuclide.

PCBs have been detected at a maximum concentration of 10 mg/kg at a depth of 1 m (3 ft) bgs. This concentration produced a calculated hazard index equal to $2\text{E}+00$ due to the combination of the soil ingestion ($\text{HQ}=1\text{E}+00$) and the homegrown produce ingestion ($\text{HQ}=8\text{E-}01$) exposure routes. The sample that produced the 10 mg/kg PCB detection was collected from the inside of the buried pipe at CFA-13. The pipe was cut approximately 30 ft from the CFA-13 drywell, and the pipe and the drywell were removed after the sample was collected. Visual inspection of the soil beneath the pipe showed no signs of contamination indicating that the PCB contamination is no longer present at CFA-13. There is no other source of PCB contamination within the site boundaries.

The ecological concern at CFA-13 is the risk to receptors from exposure to lead and mercury.

8.4.2 OU 4-02: CFA-15 Dry Well

The CFA-15 dry well was located northwest of Building CFA-674. An investigation identified a floor drain inside building CFA-674 with piping connected to the dry well; the dry well may have received laboratory liquid waste and solid calcined waste. CFA-15 was excavated during the 1997 WAG 4 Miscellaneous Sites 1997 Non-Time Critical Removal Action during November 1997. Soil was excavated to a depth of 2.4 m (8 ft). Piping that was connected to the dry well and the west wall of Building CFA-674 was cut and dry-packed with grout.

Post-removal data from the 1997 removal action was used to characterize the residual nature and extent of contamination at CFA-15. These data indicate that subsurface soils from 0.61 to 4.9 m (2 to 16 ft) bgs at CFA-15 contain residual levels of Ra-226 above contaminant screening levels.

The potential exposure route and associated COC that produce estimated excess cancer risks greater than $1\text{E-}04$ is external radiation exposure to Ra-226 by future residents. Ra-226 is a naturally occurring radionuclide in the U-238 decay chain. It is typically found in all soils at the INEEL at a nominal concentration of 1 pCi/g. The laboratory results will typically report concentrations at approximately 2 pCi/g (Giles 1998). The risk-based concentration for Ra-226 is 0.52 pCi/g, consequently even at background concentrations, Ra-226 will appear to present an unacceptable risk. Concentrations at CFA-15 are at background levels when corrected for instrument detection. In addition, Ra-226 was not disposed to the drywell and therefore should be considered to be a naturally occurring radionuclide. No contaminants have been detected at CFA-15 that result in an estimated HQ greater than 1.0.

8.4.3 OU 4-04: CFA-41 Excess Drum Storage (south of CFA-674)

The ecological concern at CFA-41 is the risk to receptors from exposure to TPH.

8.4.4 OU 4-05: CFA-04 Pond

CFA-04 consists of a shallow pond located southeast of the termination of Nevada Street which was formerly used for the disposal of wastes from operations at the CFA-674 CEL. The CEL operated from 1953 until 1965 to conduct pilot studies of a nuclear waste calcining process on simulated (no fuel) nuclear fuel rods. There are no current discharges from the building to the pond.

Data from the 1994, 1995, 1997, and 1998 sampling activities were used to characterize the contamination nature and extent of contamination at CFA-04. These data indicate that surface and subsurface soils [0 to 2.4 m (0 to 8 ft) bgs] at CFA-04 are contaminated with mercury. Also, soil in the pond bottom and the windblown area is hazardous for mercury under RCRA.

The potential exposure route and the associated COC that produce estimated hazard quotients greater than EPA permissible levels is ingestion of mercury in homegrown produce by future residents. This exposure route is associated with an estimated hazard index of 62. No contaminants have been detected at CFA-04 that result in an estimated excess cancer risk greater than $1\text{E-}04$.

The ecological concern at CFA-04 is the risk to receptors from exposure to a mercury.

8.4.5 OU 4-05: CFA-17/47 Fire Department Training Area, bermed and Fire Station Chemical Disposal

The ecological concern at CFA-17/47 is the risk to receptors from exposure to xylene.

8.4.6 OU 4-06: CFA-43 Lead Storage Area

The ecological concern at CFA-43 is the risk to receptors from exposure to lead.

8.4.7 OU 4-07: CFA-12 French Drain (south drain)

This site consists of two french drains (commonly referred to as the north and south french drains) located east of the north corner of Building CFA-690, which housed several laboratories and offices

operated by the DOE RESL. The french drains were unlined concrete cylinders approximately 0.6 m (2 ft) in diameter which extended to 1.8 m (6 ft) bgs.

A removal action was performed at CFA-12 in July 1995, concurrent with the OU 4-09 Track 2 investigation. Soil was removed to a depth of approximately 2.4 m (8.5 ft); therefore soils from the surface to the basalt at CFA-12 are considered clean. The north french drain was screened from further evaluation following the Track 2 investigation. Several radionuclides detected in the subsurface soil at 2.6 m (8.5 ft) bgs were slightly above background concentrations and are present in a subsurface basalt fracture located northeast of the south french drain.

The exposure route and the associated COC that produce estimated risks greater than $1\text{E-}04$ is external radiation exposure to Cs-137 to future residents. Cs-137 was detected in a fracture of the basalt bedrock at a depth of 2.6 m (8.5 ft) and is considered inaccessible to a future residential receptor. It is assumed in the BRA that a resident would excavate to a depth 3.2 m (10 ft) and bring potentially contaminated soil to the surface where exposure would occur. The primary exposure pathway at this site however is not complete due to the fact that all contaminated soil was removed from the site and remaining contamination is present only in a fracture of the basalt, which is inaccessible to the resident. No contaminants have been detected at CFA-12 that result in an estimated HQ greater than 1.0.

The ecological concern at CFA-12 is the risk to receptors from exposure to pentachlorophenol. This contaminant was not quantitatively assessed because there is no TRV.

8.4.8 OU 4-08: CFA-08 Drainfield

The CFA-08 drainfield is located approximately 450 m (1,476 ft) northeast of the CFA-08 sewage plant and was operated from 1944 to 1995. The CFA-08 sewage treatment plant was used to treat CFA process wastewaters from 1953 to 1995. The drainfield has received treated effluent from the sewage treatment plant from 1944 to 1995.

Analytical data from the 1994 and 1997 sampling activities were used to characterize the contamination nature and extent at CFA-08. Measured concentrations indicate that surface and subsurface soils from 0 to 2.4 m (0 to 8 ft) bgs at CFA-08 are contaminated with radionuclides.

The potential exposure routes and the associated COCs that produce estimated risks greater than $1\text{E-}04$ include external radiation exposure to Cs-137 to current and future occupation workers, and to future residents. No contaminants have been detected at the CFA-08 drainfield that result in an estimated HQ greater than 1.0. Detections of Cs-137 occur from ground surface to 2.4 m (8 ft) bgs. Concentrations of Cs-137 are highest in the top 0.9 m (3 ft) of soil.

The ecological concern at CFA-08 is the risk to receptors from exposure to mercury and chloromethane. Chloromethane was not quantitatively assessed because there is no TRV.

8.4.9 OU 4-09: CFA-10 Transformer Yard Oil Spills

CFA-10 is the site of possible PCB spills from storage of electrical transformers and of solvent and metal wastes disposed to the ground from welding shop operations.

No contaminants have been detected at CFA-10 that result in estimated risks greater than $1\text{E-}04$ or estimated HQs greater than 1.0, but lead has been detected in surface soil at concentrations that exceed the EPA 400 mg/kg lead screening for residential soil.

Measured concentrations indicate lead contamination is restricted to surface soils from 0 to 0.15 m (0–0.5 ft) bgs. Analytical data results for lead at CFA-10 are available for eight sampling locations; concentrations at five of these locations exceed the 400 mg/kg screening level. In addition, sample results at two locations are hazardous for lead under RCRA.

The ecological concern at CFA-10 is the risk to receptors from exposure to copper and lead.

8.4.10 OU 4-11: CFA-05 Motor Pool Pond

The ecological concern at CFA-05 is the risk to receptors from exposure to cadmium, copper, lead and mercury and 4-methyl-2-pentanone. There is no TRV for 2-methyl-2-pentanone, therefore this contaminant was not quantitatively assessed.

8.4.11 OU 4-12: CFA-02 Landfill II

The ecological concern at CFA-02 is the risk to receptors from exposure to lead and 4-methyl-2-pentanone, acetone, dibenzofuran and pentachlorophenol. There are not TRVs for 4-methyl-2-pentanone, dibenzofuran and pentachlorophenol, therefore these contaminants were not quantitatively assessed.

The cumulative assessment of the groundwater exposure pathway at WAG 4 indicates that potential excess cancer risks do not exceed the EPA permissible risk levels for the occupational and residential exposure scenarios. This assessment was made using site-specific soil contamination data, groundwater data, subsurface data from well logs, and GWSCREEN modeling. The limitation of these data, especially groundwater and subsurface data, from well logs is discussed in Sections 4 and 6.

Subsurface data from well drilling logs was used to determine overall interbed thickness in the vadose zone. The assumed continuity of the interbeds, used in the GWSCREEN model, is based on these data, which are limited.

Groundwater data was collected infrequently from monitoring wells upgradient from CFA since the 1950's. However, the primary focus of past monitoring programs has been contaminants from INTEC and other upgradient sources. While several monitoring wells were added downgradient of the CFA Landfills in 1995, these wells are not downgradient of most of the WAG 4 potential release sites. Three additional monitoring wells, drilled in 1996, are downgradient WAG 4, however monitoring data is limited.

9. DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

The introduction of this section discusses the overall scope, format, and content of the Operable Unit (OU) 4-13 feasibility study (FS) report, including assumptions used in preparing the report. Section 9.1 introduces the format of the comprehensive FS and the screening and disposition of OU 4-13 sites of concern. Section 9.2 lists assumptions developed in scoping the OU 4-13 FS. Section 9.3 presents the development of remedial action objectives (RAOs), identifies contaminants of concern (COCs) and media and exposure pathways of concern, and identifies potentially applicable or relevant and appropriate requirements (ARARs). Section 9.4 presents the development of remedial alternatives. Individual remedial technologies are identified and screened in Section 9.5.

9.1 Site Screening Process

This FS is comprehensive, in that remedies are identified for all sources of contamination at Waste Area Group (WAG) 4 that exceed the allowable risk range. Table 9-1 identifies soil release sites determined to present cumulative human health risks greater than $1E-04$ and/or a hazard index (HI) greater than 1, respectively, for one or more exposure scenarios; and/or that contain maximum lead concentrations in soil greater than 400 mg/kg; and/or soil release sites with an ecological risk hazard quotient (HQ) greater than 10.0, for which maximum ecological COC concentrations are greater than 10 times background concentrations. The Central Facilities Area (CFA)-04 pond, the CFA-08 Sewage Treatment Plant and Drainfield, and the CFA-10 Transformer Yard Oil Spills are the only soil release sites with risks, HIs, or lead levels exceeding human health criteria.

Hazard indices for the future residential scenario at CFA-04 are 60.0 and 2.0 for homegrown produce ingestion and soil ingestion, respectively. Mercury is the only human health COC. Human health risks for the future residential scenario at CFA-08 are $4E-04$ due to external radiation exposure to Cs-137. Lead concentrations at CFA-10 exceed EPA's screening level.

Tables K-1 through K-13 in Appendix K of the OU 4-13 RI/BRA identify soil release sites determined to present ecological risks greater than a HQ of 10.0. The procedure for ecological risk assessment (ERA) evaluated all the Federal Facility Agreement and Consent Order (FFA/CO) sites and determined that 13 release sites have a potential source of contamination and/or a pathway to ecological receptors. These sites were evaluated using the general approach as discussed in Section 7 of the RI/BRA. The results of the ERA evaluation of the remaining sites are presented as a range of HQs calculated for functional groups present as listed in Section 11. Due to the uncertainty in the ERA methods, HQs are used only as an indicator of risk and should not be interpreted as a final indicator of actual adverse effects to ecological receptors. An evaluation of these results presented in Section 7.4 of the RI/BRA report determined that sites CFA-02, -04, -05, -10, -17, -44, and -48 potentially present significant risks to ecological receptors.

A HQ of 10.0 was used for screening ecological risk sites to be addressed in the FS, based on discussions with regulatory agencies. Sites CFA-02, -44, and -48 were screened from further consideration as ecological risk on this basis. Additionally, maximum reported ecological COC concentrations less than 10 times background concentrations were screened from further consideration. Sites CFA-05 and -17 were eliminated as ecological risk on this basis. Ecological risk sites of concern retained after screening include CFA-04 and -10. The WAG 4 environmental COCs in soil include copper, lead, and mercury.

Table 9-1. The WAG 4 human health risk soil release sites of concern retained after BRA screening^a.

Group/Site	Exposure Scenario	Pathway	COPCs	Excess Cancer Risk/HI	Total
CFA-10	0-year occupational	NA	Pb	NA	NA
	100-year residential	NA	Pb	NA	Pb levels exceed residential PRG
CFA-04 Pond	0-year occupational	Soil ingestion	As	2E-06	2E-06
			Hg	7E-01 (HI)	7E-01 (HI)
		Dermal absorption	As	1E-06	1E-06
		External radiation exposure	U-238	1E-06	1E-06
	Total for scenario				5E-06 7E-01 (HI)
	100-year occupational	Soil ingestion	As	2E-06	2E-06
			Hg	7E-01 (HI)	7E-01 (HI)
		Dermal absorption	As	1E-06	1E-06
		External radiation exposure	U-238	1E-06	1E-06
	Total for scenario				5E-06 7E-01 (HI)
	100-year residential	Soil ingestion	As	3E-05	3E-05
			Hg	1E-01 (HI)	2E+00 (HI)
				1E+00 (HI)	
		Dermal absorption	As	5E-06	5E-06
		Homegrown produce ingestion	As	3E-06	3E-06
			Hg	6E+01 (HI)	6E+01 (HI)
		External radiation exposure	U-238	5E-06	5E-06
	Total for scenario				4E-05 4E+01 (HI)

Table 9-1. (continued).

Group/Site	Exposure Scenario	Pathway	COPCs	Excess Cancer Risk/HI	Total
CFA-08: Sewage Treatment Plant Drainfield	0-year occupational	Soil ingestion	Cs-137	1E-06	2E-06
		External radiation exposure	Cs-137	2E-03	2E-03
	Total for scenario				2E-03
	100-year occupational	External radiation exposure	Cs-137	2E-04	2E-04
	Total for scenario				2E-04
	100-year residential	Homegrown produce ingestion	Cs-137	4E-05	4E-05
		External radiation exposure	Cs-137	4E-04	4E-04
	Total for scenario				4E-04
a. Risks and HIs contributing to cumulative risks greater than 1E-06 and/or cumulative HIs greater than 1.0 only are shown.					

9.2 Assumptions

Several assumptions were developed to facilitate preparation of this FS. These assumptions were developed in conference calls with the Idaho Department of Health and Welfare (IDHW), U.S. Environmental Protection Agency (EPA) Region 10, and U.S. Department of Energy Idaho Operations Office (DOE-ID) in February 1998 and are listed below.

9.2.1 General Assumptions

The general assumptions include:

1. The *Long-Term Land Use Future Scenarios for the INEL* (DOE 1995a) document identified the role of the CFA for the next 100 years as the “primary technical service and support area.” The CFA is therefore assumed to be institutionally controlled for that time, including access restrictions and other administrative and physical security controls. These types of controls on physical access are assumed to end in 2095.
2. Groundwater contamination that may enter WAG 4 from upgradient sources will be addressed by the WAG from which the contaminant plume originated.
3. In the event that currently unknown contaminant releases are encountered at OU 4-13 in the future, the investigation and remedial response will be required to meet OU 4-13 FS RAOs. This will be stated in the OU 4-13 Record of Decision (ROD).
4. It is assumed that current or future facilities and operations at CFA will not interfere with remedial activities. Remediation of any site of concern could begin within 15 months after signature of the ROD.
5. Innovative technologies will be evaluated in this FS only if they have been successfully demonstrated at pilot-scale or greater, for contaminants and media similar to those found at OU 4-13.
6. A soil repository (the Idaho National Engineering and Environmental Laboratory [INEEL] Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Disposal Facility or ICDF) is assumed to be available on the INEEL, south of the Idaho Nuclear Technology and Engineering Center (INTEC), by 2001. This facility will be permitted to receive essentially any contaminated soil generated on the INEEL, including mixed wastes. Disposal capacity for Resource Conservation and Recovery Act (RCRA) hazardous or mixed waste soils is assumed to exist at this facility by 2002. Excavation and disposal of WAG 4 soils would be coordinated with ICDF operations to allow for use of this disposal option.

9.2.2 Assumptions for RAO Development

The assumptions for the RAO development include:

1. Soil contaminants are defined as COCs if, either singly or cumulatively, they currently result in, or are predicted to result in the future, an excess cancer risk of greater than $1\text{E-}04$, and/or a HI greater than 1.0. This does not include naturally occurring elements and compounds not attributable to an OU 4-13 release.

2. The RAOs for soil will be defined by COC and exposure pathway.
3. Soil release site RAOs would be met everywhere within the extent of soil contamination resulting from WAG 4 sources.
4. Ecological risks are assumed to be reduced by active remedial measures implemented to reduce human health risks, for those sites presenting risks to both. Ecological risks will be reevaluated in the WAG 10 comprehensive ERA to determine if the actions are truly protective of ecological receptors.
5. Ecological risk sites with HQs >1 were screened. Those with HQs greater than 10.0 and for which maximum COC concentrations are at least 10 times background concentrations are evaluated in this FS. Both screening levels were proposed by EPA Region 10^a based on the "conservative" nature of the ERA, and were accepted by DOE-ID and the IDHW.
6. EPA's screening level soil lead concentration of 400 mg/kg will be used as a human-health preliminary remediation goal (PRG).

9.3 Remedial Action Objectives

Remedial action objectives for OU 4-13 were developed in accordance with the NCP and CERCLA RI/FS guidance, and were refined through discussions among agencies (IDHW, EPA Region 10, and DOE-ID). The RAOs are based on the results of both the human health and ecological risk assessments and are specific to the COCs and exposure pathways developed for OU 4-13.

The RAOs specified for protecting human health are expressed both in terms of risk levels and exposure pathways, because protection can be achieved by reducing contaminant levels, as well as by limiting or eliminating exposure pathways. The RAOs specified for protecting the environment are intended to preserve and/or restore the resource.

The OU 4-13 BRA evaluated current and future occupational and residential use scenarios (post-2095). According to the *Long-Term Land Use Future Scenarios for the INEL* (DOE 1995a) document the INEEL is assumed to remain under government management for at least 100 years from 1995, and the CFA will remain a restricted-access industrial use site.

Current onsite workers, hypothetical future workers and residents, and ecological receptors were considered in developing the RAOs. The RAOs cited below would be met within the boundary of each soil release site requiring remedial action, which is defined as the areal extent of COCs resulting in cumulative human health risks greater than 1E-04, and/or a cumulative human health HI greater than 1.0, for either the occupational or future residential scenarios, via any soil exposure pathway; and/or ecological risks greater than a HQ of 10.0. The RAOs for ecological risk may be revised, after completion of the WAG 10 INEEL-wide ERA.

Based on the preceding discussion, the following OU 4-13 RAOs have been developed to protect human health and the environment:

a. Conference call on 2/9/98 with EPA Region 10, DOE-ID, and the IDHW.

For Current and Future Workers and Future Residents, Due to Risks Presented by Contaminated Soils

- Inhibit direct exposure to radionuclide COCs, at any OU 4-13 soil release site, that would result in a total excess cancer risk for the site greater than 1E-04.
- Inhibit ingestion of radionuclide and non-radionuclide COCs, at any OU 4-13 soil release site, by all soil exposure routes (including soil ingestion, inhalation and homegrown produce ingestion), that would result in a total excess cancer risk for the site greater than 1E-04, or a total HI greater than 1.0. This does not include lead, for which no carcinogenic slope factors or RfDs are available.

For Inhibiting Degradation of Sites where COCs Remain in Soil

- Inhibit degradation of final covers where wastes remain in place that would result in exposure to, or migration to the surface of, COCs that would result in total excess cancer risk for the site greater than 1E-04, or a total HI greater than 1.0, to current and future workers and to future residents.

For Protection of the Environment

- Inhibit ecological receptor exposures to contaminated soils resulting in a HQ greater than 10.0, where COC concentrations are at least 10 times background concentrations, as determined by the ecological risk evaluation. This does not include naturally occurring elements and compounds not attributable to OU 4-13 releases.

9.3.1 Contaminants and Sites of Concern

Contaminants of potential concern (COPCs) for human health risks identified in the RI/BRA for OU 4-13 sites of concern are summarized in Table 9-1. A final set of COCs were developed by identifying COPCs resulting in, either individually or cumulatively, site risks greater than or equal to 1E-04 and/or HIs greater than or equal to 1.0, as determined in the BRA for all exposure scenarios considered. Lead present at concentrations greater than 400 mg/kg is also defined as a COC. The OU 4-13 human health risk soils COCs include Pb, Hg, and Cs-137. No groundwater COCs were identified.

The RCRA characterization performed in 1998 determined that a fraction of CFA-04 soils are RCRA toxicity characteristic wastes for mercury (D009), and that a fraction of CFA-10 soils are RCRA toxicity characteristic wastes for lead (D008).

Sites of concern are those sites with cumulative risks greater than 1E-04, a cumulative HI greater than 1.0 and/or lead concentrations greater than 400 mg/kg. The OU 4-13 sites with cumulative risks greater than 1E-04 and/or with HIs greater than 1.0 are also shown in Table 9-1.

Contaminants and sites of concern for ecological risks are discussed in Section 7 of the RI/BRA Report, and are listed in Tables K-1 through K-13 in Appendix K. Ecological risk COCs are those resulting in ecological risks greater than a HQ of 1.0, and for which maximum concentrations are greater than 10 times INEEL background soil concentrations. Ecological risk sites of concern for screening purposes, are defined as those with HQs greater than 10.0 and for which COC maximum concentrations are at least 10 times background concentrations.

9.3.2 Media and Materials of Concern

Media and materials of concern for CFA-10 consist almost entirely of contaminated soils. Minor amounts of debris are present at CFA-04, primarily buried in the sides of the pond, including asbestos roofing material and other roofing debris. A 122 m (400 ft), 15-cm (6-in.) diameter drain line supplies the pond; however, this line will be addressed by the decontamination and dismantlement (D&D) program. At CFA-10, a concrete pad 6 m (20 ft) wide extends approximately 18 m (60 ft) across the width of the yard.

The CFA-08 drainfield contains approximately 12,192 m (40,000 ft) of gravel-filled trenches containing clay drainage tiles, supplied by concrete feeder pipes from the concrete diversion boxes. Individual elements are described below.

9.3.2.1 Drain Tiles. There are five drainfield areas each with 20, 61-m (200-ft) lines. Total length of drain tiles is 6,096 m (20,000 ft). Each drain tile section is 10-cm (4-in.) diameter red clay pipe in 1.2-m (4-ft) length sections, with a wall thickness of 2.5 cm (1 in.), laid with a 2.5-cm (1-in.) gap between ends. The drain tiles are 0.6 m (2 ft) below ground surface (bgs). Each line was installed in a trench, 0.8 m wide \times 2.4 m deep (2.5 ft wide \times 8 ft deep), filled with screened sewer gravel. The top 30 to 46 cm (12 to 18 in.) were backfilled with excavated soil. Some tile sections likely contain low level radioactive sludge.

9.3.2.2 Feeder Pipes. A 20-cm (8-in.) diameter concrete feeder line approximately 2.4 m (8 ft) bgs runs parallel to the drainfield for approximately 244 m (800 ft) and supplies the diversion boxes. It is reportedly 1/3 filled with nonhazardous (samples from the sludge were collected and analyzed for toxicity characteristic leaching procedure [TCLP] during the RI/FS) low level radioactive sludge.

Two 10-cm (4-in.) cast iron feeder lines also run parallel to the drainfield. The total length of 10-cm (4-in.) pipe is 274 m (900 ft). It is reportedly filled with nonhazardous low-level radioactive sludge.

9.3.2.3 Concrete Diversion Boxes. Five concrete diversion boxes with 20-cm (8-in.) thick walls and a wood top supply the drain tiles. The inside dimension of each box is 0.6 x 0.6 m (2 \times 2 ft). The height is between 0.9 and 1.5 m (3 and 5 ft). There is a metal headgate inside each box. The boxes reportedly contain less than 0.3 m (1 ft) of sludge.

9.3.3 Contaminated Site Dimensions

Approximate dimensions of contaminated sites are shown in Table 9-2. Depths of remediation shown are conservative estimates, based on deepest detections reported, on estimated contaminant mobility, and the lack of human health exposure pathways for contaminants deeper than 3.0 m (10 ft) bgs.

For CFA-10 only four samples were collected for Pb analysis, and all came from the surface. In the absence of subsurface data, and based on the K_d of 100 and infiltration rate of 10 cm/year (4 in./year), both suggested in DOE (1994); and on an assumed bulk density of 1.65 and a porosity of 0.25, this would result in a retardation coefficient of 661 and a Pb transport velocity of 1.5E-02 cm/year (4.9E-04 in./year).

Using these transport parameters, it would take over 2E+03 years for Pb to travel 0.3 m (1.0 ft). Lead contamination resulting from surface releases at all sites was therefore assumed to be confined to the top 0.15 m (0.5 ft) of soil.

Table 9-2. COCs and remediation dimensions for OU 4-13 sites of concern.

Site	Human Health COCs	Ecological Risk COCs	Maximum Depth of Remediation m (ft) bgs	Area m ² (ft ²)	Volume m ³ (ft ³)
CFA-04: Disposal Pond at CFA-674	Hg	Cu, Hg	2.13–3.05 (7–10)	6.88E+03 (7.43E+04)	6.29E+03 (2.23E+05)
CFA-08: Sewage Treatment Plant Drainfield	Cs-137	NA	0–3.05 (0–10)	1.85E+04 (2.00E+05)	5.64E+04 (2.00E+06)
CFA-10: Transformer Yard Oil Spills	Pb	Pb	0–0.15 (0–0.5)	8.08E+02 (8.70E+03)	1.23E+02 (4.35E+03)

NA = Not Applicable (no risk).

The average depth of the CFA-04 pond is 2.13 m (7 ft) bgs. For mercury contamination at CFA-04 it was determined that soils are contaminated above PRGs to a depth of at least 0.9 m (3.0 ft) below the bottom of the pond (3 m [10 ft] bgs), based on July 1998 sampling data provided in Appendix B. The actual depth of contamination is unknown; however, remediation to a depth of 3 m (10 ft) bgs (i.e., 0.9 m [3.0 ft] below the bottom of the pond) would eliminate human health and ecological exposure pathways, assuming the pond would be backfilled as part of any remedy. Based on the July 1998 sampling, approximately 467 m³ (611 yd³) of soil in the pond are estimated to be RCRA toxicity characteristic wastes for mercury (D009).

The CFA-04 site includes a windblown area of mercury contamination outside the pond, with contamination above PRGs, as shown in Figure 3-1. The depth of contamination is assumed to not exceed 0.15 m (0.5 ft) bgs. The estimated total windblown area and volume are 682 m² (1,686 ft²) and 645 m³ (843 yd³), respectively. Based on the July 1998 sampling, approximately 141 m³ (185 yd³) of the windblown soils are estimated to be RCRA toxicity characteristic wastes for mercury (D009).

Contamination at the CFA-08 Sewage Treatment Plant drainfield was assumed to extend to 3 m (10 ft) bgs for purposes of identifying remedial alternatives, based on Cs-137 detection above the PRG at depths of 1.2 to 2.4 m (4 to 8 ft) bgs; and on the depth of the trenches (2.4 m [8 ft] bgs) containing the drain tiles. The maximum depth of remediation is based on maximum depth of soil contamination that could result in receptor exposures above allowable levels, as defined in the RI/BRA.

9.3.4 Exposure Pathways of Concern

Human health exposure pathways of concern identified in the OU 4-13 BRA are those resulting in risks greater than 1E-06 and/or HIs greater than 0.1, and are listed in Table 9-1. The cumulative HI for CFA-04 exceeds the allowable range for the residential 100-year scenario, primarily due to ingestion of mercury-contaminated homegrown produce. Cumulative risks at CFA-08 exceed the allowable range for the 0-year occupational scenarios, and for the 100-year residential scenario, due to external Cs-137 exposure. Lead concentrations in soil at CFA-10 exceed the 400 mg/kg EPA screening level.

Ecological risks at OU 4-13 sites are summarized in Tables K1 through K13 in Appendix K of the RI/BRA. Sites with HIs greater than 10.0 for ecological receptors, and for which COC concentrations are greater than 10 times background concentrations, are listed in Table 9-2.

Current administrative controls implemented under DOE Order 5480.11 require that worker radiological exposures be as low as reasonably achievable (ALARA). Worker risks identified in the BRA were estimated assuming no administrative or engineering controls; however, ALARA controls reduce occupational risks to allowable levels at all sites. Under ALARA, radiation control fences are maintained to restrict worker access, the safe work permit process defines administrative and engineering controls on exposures for workers entering the areas, and monitoring by radiological control technicians during work in radiation control areas limit exposures. These activities will be maintained during the 100-year institutional control period at all WAG 4 sites, reducing radiological risks to workers to allowable levels.

9.3.5 Preliminary Remediation Goals

The PRGs are quantitative cleanup levels, based primarily on ARARs and risk-specific doses (EPA 1988). The PRGs are used in planning remedial actions and assessing effectiveness of remedial alternatives. Final remediation goals are based on results of the BRA, and evaluations of expected exposures and risks for alternatives, and consider the effects of multiple contaminants. The OU 4-13 ROD will present final remediation goals.

The 1E-04 risk or HI equal to 1 level, which ever is more restrictive for a given contaminant, is the basis for determining PRGs for OU 4-13. Therefore, PRGs for individual COCs were defined by calculating soil concentrations that would result in excess cancer risks equal to 1E-04, or health risks resulting in a HI equal to 1, for hypothetical residents present at the end of the 100-year institutional control period, summed for all pathways and all COCs present at each site. A given COC may have different PRG values at different sites, because some sites have more COCs than others do. For example, if a given site has only one COC requiring remediation, the PRG would equal the contaminants risk of 1E-04 or HI of 1 residential risk-based concentration. If, however, the site has two COCs requiring remediation, the PRG for each would equal the risk of 5E-05 or HI of 0.5 concentration for each COC, so that the total risk for the sites would equal 1E-04 ($2 \times 5E-05 = 1E-04$), or the total HI for the site would equal 1.0 ($2 \times 0.5 = 1.0$). This analysis method assures that each contaminant would have to be remediated to the same risk level in order to achieve an acceptable risk for the site. The PRGs calculated for OU 4-13 sites are provided in Table 9-3.

Table 9-3. PRGs for OU 4-13 sites.

Site	Contaminant	PRG ^a (pCi/g or mg/kg)
CFA-04	Human health: Hg	1.27
	Ecological: Cu	3.2E+02
	Hg	7.4E-01
CFA-08	Human health: Cs-137	2.3E+01
	Ecological: NA	
CFA-10	Human health: Pb	4.0E+02
	Ecological: Pb	2.3E+02

a. Ecological risk PRGs for all COCs = 10X background concentrations reported in Section 7 of the RI/BRA report.

A PRG for lead in soils was developed, based on EPA guidance recommending that cleanups at CERCLA sites for residential land use result in lead concentrations not to exceed 400 mg/kg (EPA 1994). The 400 mg/kg level was determined using the EPA Uptake Biokinetic Model to predict blood lead levels in children, the most sensitive segment of the potentially exposed population. Lead has not been demonstrated to be a carcinogen in humans or animals, and no slope factors have been determined.

9.4 Identification of Alternatives

9.4.1 General Response Actions

General Response Actions (GRAs) are broad categories of remedial actions that will satisfy RAOs for the contaminated media at OU 4-13 sites. In order to protect human health and the environment, the intent of GRAs is to eliminate source-to-receptor pathways by preventing external exposure to and direct contact with contaminants, and by reducing or eliminating contaminant migration to clean media or to biota. Soil, sediments, concrete and tile pipe, gravel and debris are the contaminated materials potentially targeted for remediation at the OU 4-13 sites.

The GRAs, individually or in combination with other GRAs, can satisfy RAOs in one of two ways: (1) contaminants can be destroyed or reduced in concentration to levels posing acceptable risks to human health and the environment or (2) contaminants can be isolated from potential exposure and migration pathways to decrease risks to human health and the environment. Contaminant destruction is the preferred method because it ensures that RAOs have been satisfied. However, radionuclide and toxic metal contamination within the OU 4-13 sites cannot be destroyed and must therefore be reduced in concentration or isolated from potential exposure and migration pathways.

A range of GRAs and combinations of GRAs that could achieve varying degrees of protectiveness of human health and the environment, and compliance with RAOs, were defined. Six GRAs and combinations of GRAs identified for contaminated media at OU 4-13 sites include:

- No action (with monitoring)
- Institutional controls
- Containment and institutional controls
- Removal and disposal and institutional controls
- Removal, treatment ex situ, disposal and institutional controls
- Treatment in situ and institutional controls.

A brief description of each GRA identified for the OU 4-13 sites is presented below.

9.4.1.1 No Action with Monitoring. The no action with monitoring GRA does not involve active remedial actions with the exception of environmental monitoring. Monitoring would serve to identify potential contaminant migration or other potential changes in site conditions that may warrant future remedial actions. Types of environmental monitoring considered for use at the OU 4-13 sites are defined in the description of alternatives presented in Section 9.5. Monitoring is an institutional action that can be assumed to remain in effect for at least 100 years.

9.4.1.2 Institutional Controls. Institutional controls refer to actions taken by responsible authorities to minimize potential danger to human health and the environment. Institutional controls include ongoing actions that can be maintained only as long as the responsible authority is in control of the site; as well as deed restrictions that limit land use after transfer from the responsible authority. In order to remain consistent with the BRA (Section 6), the 100-year institutional control period is assumed to begin in 1998.

Long-term environmental monitoring, as for the No Action With Monitoring alternative; access restrictions, including fencing, deed restrictions and other measures; and surface water diversion would be established and maintained as necessary where contamination remains in place to provide early detection of potential contaminant migration and to control exposures to contaminants. These programs would be implemented annually for the first 5 years following signature of the ROD. The need for further institutional controls would be evaluated and determined by the Agencies during subsequent 5-year reviews, which are required under 40 CFR 400.430(f)(4)(ii) at sites where contaminants remain above levels that allow for unrestricted use.

9.4.1.3 Containment and Institutional Controls. This GRA utilizes a combination of containment actions and institutional controls. Containment refers to remedial actions taken to isolate contamination from the accessible environment, and for soil release sites typically includes capping. Institutional controls are described in Section 9.4.1.2 above. Isolating contaminants of concern would eliminate potential exposure pathways to human or environmental receptors, however institutional controls, described previously, are assumed to be required to ensure effectiveness wherever contaminants remain in place above PRGs. Five-year reviews would ensure continued effectiveness of the remedy.

9.4.1.4 Removal and Disposal. This GRA involves complete removal of material contaminated at concentrations greater than PRGs from the sites, followed by disposal at an appropriate location. Monitoring and/or institutional controls would not be required where all contamination above allowable levels was removed. However, if contamination above PRGs remained at the site, institutional controls would be required to monitor and maintain the effectiveness of this remedy. At a minimum, these would include 5-year reviews and deed restrictions.

9.4.1.5 Removal, Treatment Ex Situ, and Disposal. This GRA consists of excavating contaminated soils and debris and treating them to reduce the toxicity, mobility, and/or volume of the contamination. Treatment would be required for all RCRA LDR wastes excavated and removed from the AOC.

No method exists for destroying radionuclide contaminants or reducing their toxicity. However, volumes of contaminated media may be reduced and some toxic metals may be rendered less toxic through treatment. Previous actions at similar sites, including removal actions at WAG 4, were reviewed to identify and screen treatment technologies potentially effective at OU 4-13.

Monitoring and/or institutional controls would not be required where all contamination above allowable levels was removed. However, if contamination above PRGs remained at the site, institutional controls would be required to monitor and maintain the effectiveness of this remedy. At a minimum, these would include 5-year reviews and deed restrictions.

9.4.1.6 Treatment In Situ. This GRA consists of implementing technologies capable of immobilizing or reducing the toxicity or volume of contaminants in situ. No method exists for destroying radionuclide contaminants or reducing their toxicity. However, volumes of contaminated media may be reduced, and some toxic metals may be rendered less toxic through in situ treatment. Previous actions at similar sites were reviewed to identify and screen treatment technologies potentially effective at OU 4-13.

Institutional controls would be required where contamination remains in place above PRGs, as described previously.

9.5 Identification and Screening of Technologies

This section discusses the methods used to identify remedial technologies and process options representative of the GRAs described previously. Treatment process options demonstrated at similar sites, and/or results of INEEL treatability studies, were reviewed to identify and screen treatment process options potentially effective at OU 4-13. Technologies and response actions demonstrated to be effective for sites with similar contaminants and contaminated media types, and in particular those demonstrated at the INEEL, are used to define applicable process options and technology types. Innovative and emerging technologies that have been demonstrated at least at pilot scale are also considered.

Table 9-4 shows the identification and screening process for remedial technologies at OU 4-13. First, remedial technology types representing each GRA were identified. Then, process options representing each technology type were identified and screened based on effectiveness, implementability, and cost, relative to other processes within the same technology type. Evaluation of effectiveness considers the ability of the technology to handle the types and volumes of contaminated media present, and to meet RAOs; the potential impacts to human health and the environment during implementation; and proven reliability of the technology with respect to contaminants and conditions present at the site.

Evaluation of implementability considers both technical and administrative feasibility of the technology. Technical implementability includes consideration of technology-specific parameters that constrain effective construction and operation of the technology, with respect to site-specific conditions. Administrative implementability includes consideration of ability to obtain required permits for offsite actions; availability of treatment, storage, and disposal services; and the availability of equipment and personnel required to implement the technology.

Evaluation of cost considers relative estimates of capital and operations and maintenance (O&M) costs. Engineering judgement is used to estimate costs as high, moderate, or low, relative to other process options in the same technology type.

Technologies determined not to be effective or implementable for OU 4-13 sites and COCs were screened from further consideration. The technology screening shown in Table 9-4 is summarized below. Process options and technology types are listed under their respective GRAs.

9.5.1 No action With Monitoring

9.5.1.1 Environmental Monitoring. Monitoring would include only soil monitoring, since direct radiation exposure and soil and homegrown produce ingestion were identified as the only exposure pathways of concern in the OU 4-13 BRA. Soil monitoring could include radiation surveys over and around sites where contaminated soil and debris are left in place to determine if radionuclides have been mobilized to the surface, and/or soil sampling and laboratory analysis for toxic metals. Air monitoring would be effective only for monitoring worker exposures during remedial actions. Groundwater monitoring is currently implemented, but costs of continued groundwater monitoring were not included in long-term environmental monitoring, since OU 4-13 soil release sites were not predicted to affect groundwater.

Soil monitoring is technically and administratively implementable. Monitoring alone would not meet RAOs, but may in combination with other GRAs and technologies. Costs of soil monitoring are

Table 9-4. Summary of screening of OU 4-13 remedial technologies.

GRAs	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Screening Result
No action with monitoring	Environmental monitoring	Soil	High, when combined with other options.	High	Low	Retain
		Air	No effectiveness, except for monitoring exposures during remedial actions, since air exposures from OU 4-13 soil release sites were determined to be acceptable.	High	Low	Reject
		Groundwater	No effectiveness, since OU 4-13 soil release sites were determined to not affect groundwater.	High, already implemented	Moderate	Reject
Institutional controls	Access restrictions	Fences	High, for institutional control period only, and for human health risk reduction only.	High, for institutional control period only	Low	Retain
		Deed restrictions	High, for human health risk reduction only. Assumed to last in perpetuity.	High	Low	Retain
	Maintenance	Cap integrity monitoring and maintenance	High, for institutional control period.	High, for institutional control period	Moderate	Retain
		Surface water diversions	High, for institutional control period.	High, for institutional control period	Moderate	Retain
Excavation	Standard techniques	Backhoes and dozers	High.	High for accessible sites	Low	Retain
	Remote techniques	Robotics	Uncertain-site specific.	Uncertain, site specific	High	Reject
Containment	Capping	ET-type	High.	Moderate, high	Moderate	Retain
		SL-1-type	Moderate, does not reduce infiltration.	High	Low-moderate	Retain
		RCRA-type	Moderate.	Moderate	High	Retain

Table 9-4. (continued).

GRAs	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Screening Result	
Disposal	Landfilling	Native soil	Moderate.	High	Low-moderate	Retain	
		Concrete	Moderate.	Moderate	High	Retain	
		RWMC	High.	High, although operations currently discourages low-level rad soil disposal	High-if stated disposal costs are applied	Retain	
		ICDF	Status uncertain.	Status uncertain-currently projected to be available in 2001 for LLW soil, 2002 for hazardous-mixed soil	Low	Retain	
		INEEL landfill complex	High.	High	Low	Retain	
		Offsite MLLW landfill	High.	High	Moderate-High	Retain	
		RCRA TSDF	High for RCRA soils, won't accept rad or mixed.	High for RCRA soils, won't accept rad or mixed	High	Retain	
Treatment In Situ	Physical-chemical	NTS	High.	INEEL not an approved generator	High	Reject	
		In situ chemical stabilization	Moderate, no reduction in direct exposure risks; would reduce toxic metal risks.	Low-uncertain; site specific	Moderate	Retain	
		Chemical	Soil washing	Low.	Low	High	Retain
		Thermal	ISV	Low-moderate; no reduction in direct radiation exposure risks; would eliminate all other risks.	Low-moderate; technically complex, site specific	High	Reject
		Biological	Phytoremediation	Uncertain; currently undergoing testing at ANL-W.	Uncertain	Low	Retain, pending ANL-W test results

Table 9-4. (continued).

GRAs	Remedial Technology	Process Options	Effectiveness	Implementability	Cost	Screening Result
Treatment ex situ	Physical	Screening	Uncertain, not demonstrated for WAG 4 soils and COCs; not effective for volume reduction from Cs-137-contaminated INEEL soils in previous tests. May be effective as a pretreatment step for subsequent processes.	High	Low	Retain
		Flotation	Uncertain, not demonstrated for WAG 4 soils and COCs	Moderate-produces secondary wastestream	Moderate	Retain
		Attrition scrubbing	Uncertain, not demonstrated for WAG 4 soils and COCs; not effective for Cs-137 removal from INEEL soils in previous tests	Moderate-produces secondary wastestream	Moderate	Retain
		Segmented gate	Uncertain, potentially high for rad soil sites.	Moderate	Moderate	Retain
	Physical/Chemical	Soil washing	Uncertain, not demonstrated for WAG 4 soils and COCs; not effective for Cs-137 removal from INEEL soils in previous tests.	Low-produces secondary wastestream; site-specific treatability studies required.	Moderate	Reject
		Stabilization	Moderate. Would not significantly reduce direct radiation exposure risks, would be effective for toxic metal-contaminated soils.	Moderate	Moderate	Retain
	Thermal	Plasma torch	Moderate. Would not reduce direct radiation exposure risks, may be effective for Pb and Hg contaminated soils.	Low	High	Retain
		Mercury retort	High for Hg only.	Moderate; demonstrated at INEEL; produces secondary wastestreams	High	Retain

relatively low, while groundwater monitoring costs are moderate. For cost estimating purposes, monitoring was assumed to be 100 years; however, this duration is not driven by ARARs and could be reduced with concurrence of the regulatory agencies.

9.5.2 Institutional Controls

Institutional controls alone may meet human health RAOs during the institutional control period and longer if combined with other technologies and GRAs. Representative types of institutional controls are described below.

9.5.2.1 Fences. Access restrictions including fences are assumed to be maintained for at least the 100-year institutional control period following site closure. Fences must be accompanied by warning signs to be effective in controlling exposures to inadvertent intruders. Fences are effective in controlling human exposures by restricting access during the institutional control period, but in general are not effective in reducing ecological exposures. Fences are technically and administratively implementable. Costs are relatively low.

9.5.2.2 Deed Restrictions. Deed restrictions can be implemented if the government-owned property is ever transferred to non-government ownership. Deed restrictions are considered effective in perpetuity, and are implementable through the Record of Decision (EPA 1998). The deed discloses former waste management and disposal activities that occurred at the site, and can restrict future activities at the site through protective covenants and easements. Deed restrictions are not effective in reducing ecological exposures. Costs are relatively low.

9.5.2.3 Cap Integrity Monitoring and Maintenance. This option would apply to sites where wastes were left in place and contained under a final cover. Cover integrity monitoring and maintenance was assumed to be performed for at least the 100-year period of institutional control, to assess the physical condition of the cap, and to determine if corrective actions were required. Monitoring would include visual inspections in combination with the radiation surveys described previously under environmental monitoring to determine if animal burrows, erosion or other processes had damaged the cover or barrier to a degree requiring maintenance. Maintenance would consist of filling burrows, repairing erosion damage and subsidences, and potentially other activities.

The time required for maximum activities of Cs-137 at CFA-08 to decay to the unrestricted release level of 2.3 pCi/g was estimated as 189 years. Any cover or barrier designed for this site would be required to control exposure pathways of concern for at least those durations.

Cap integrity monitoring and maintenance would be effective and implementable for the institutional control period. Costs are estimated to be relatively moderate.

9.5.2.4 Surface Water Diversions. This option would apply to sites where wastes were left in place and contained under a final closure cover. Surface water diversions would most likely consist of maintaining existing drainage ditches and channels by regular inspection and removal of debris. No new construction would be expected to be required except as part of design of other remedial alternatives as explained in subsequent sections. Maintaining surface water diversions would be effective and implementable for the institutional control period. Costs are estimated to be moderate.

9.5.3 Excavation

Excavation technologies are described below. Soils contaminated above PRGs would be selectively excavated, to the extent feasible, using field-screening technologies to identify radionuclide activities, and toxic metal concentrations, exceeding PRGs. Instrumentation could include hand-held sodium iodide detectors for Cs-137, which were successfully used for the INEEL OU 10-06 radioactive soil consolidation; and X-ray fluorescence (XRF) spectrometers for toxic metals, also available on the INEEL. Comparing current reported XRF detection limits for Pb, Cu, and Hg (50, 50, and 200 mg/kg, respectively) (Ashe et al. 1991) to the PRGs reported in Table 9-3 indicate that the instrument could be effective for determining the extent of Pb and Cu contamination above the PRGs, but would not be useful for Hg.

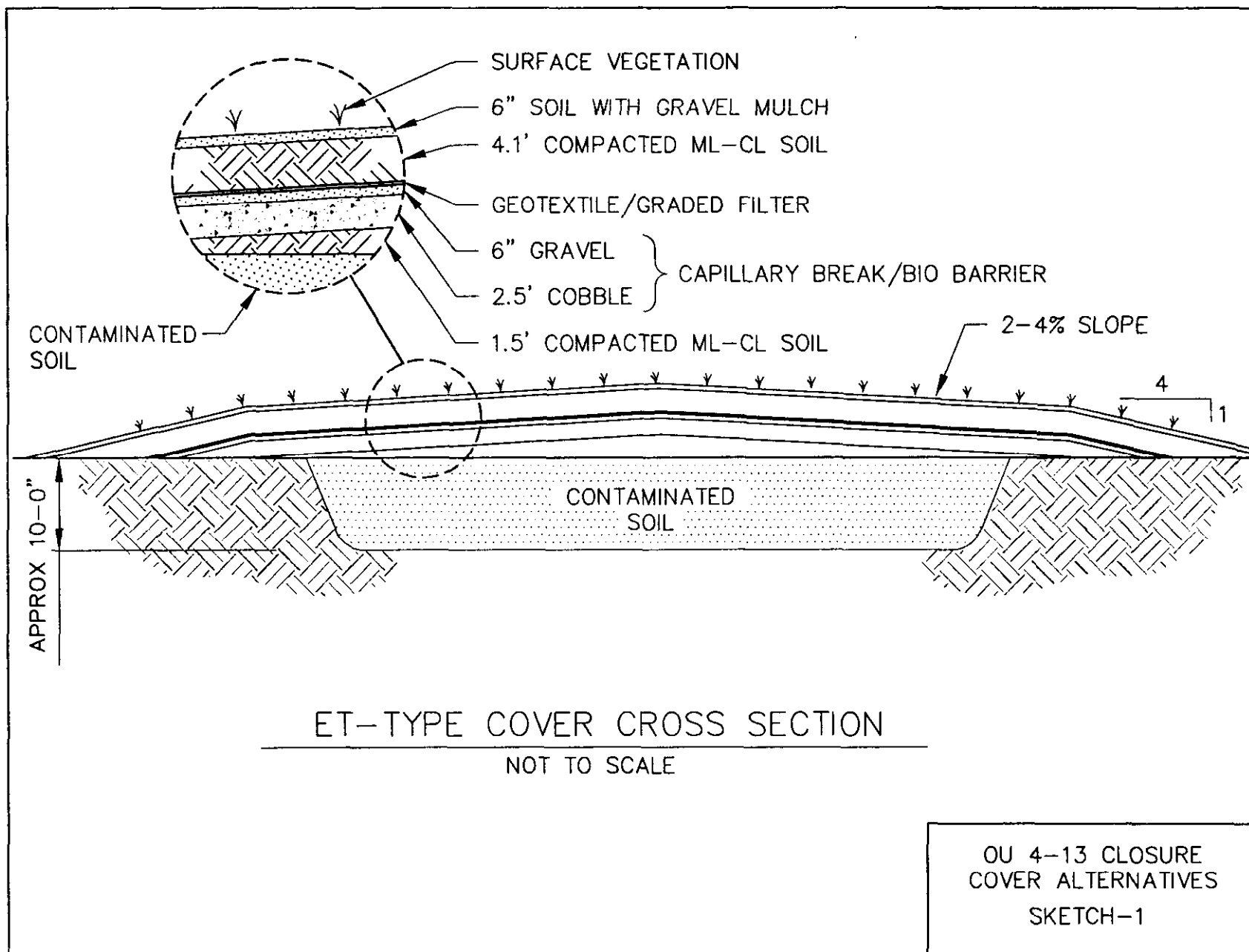
9.5.3.1 Backhoes and Dozers. These process options represent standard excavation techniques utilizing conventional equipment. Conventional equipment has been demonstrated to be completely effective for removing contaminated soil to depths of at least 8 m (25 ft) bgs at the INEEL, and potentially to greater depths depending on site conditions. Equipment operators can be shielded in positive pressure cabs as needed to reduce exposures during excavation. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. These process options are therefore considered technically and administratively feasible. Costs are considered to be relatively low.

9.5.3.2 Robotics. This process option represents non-standard excavation techniques using remote-operated equipment. These technologies are not globally demonstrated to be effective and implementable, and would have to be evaluated on a site-specific basis. No OU 4-13 soil contamination has been determined to be classified as remote handled waste (>500 mR/hr at 0.9 m [3 ft] in air); therefore, robotics are likely not required to reduce worker exposures to allowable levels. Costs are considered relatively high. This technology was therefore screened from further consideration on the basis of cost-effectiveness.

9.5.4 Containment

9.5.4.1 ET-Type (Capillary Barrier/Biobarrier) Cover. This technology is estimated to be highly effective in protecting human health and the environment and meeting RAOs for OU 4-13. The capillary barrier/biobarrier cap, shown in Figure 9-1, consists of layers of fine-grained earthen materials overlying coarse-grained media. The large variation in soil moisture tension between the two layers results in infiltrating water being retained in the upper, fine-grained layers by capillary attraction, within the root zone of surficial vegetation, until saturated. Evaporation and plant transpiration can remove essentially all precipitation that falls in arid regions, including the INEEL high desert environment (Anderson et al. 1992), typically preventing development of saturated conditions and preventing drainage through the capillary barrier (Keck et al. 1992). A base course of asphalt or concrete may be used to further limit infiltration. The capillary break would also serve as a biobarrier, inhibiting biointrusion, or alternatively a separate layer can be used for this function.

Several variations of the ETC design are currently undergoing field testing at the INEEL Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) (Anderson 1997a 1997b, and Bhatt and Porro 1998), and have been tested successfully at Hanford and Los Alamos (Nyhan et al. 1990). The Hanford Permanent Isolation Surface Barrier (PISB) includes multiple low-permeability base courses, as well as a 1.5 m (5 ft) thick fractured basalt layer that serves as a capillary break, biointrusion and human intrusion barrier. Many variations on the basic engineering technology (ET) design are possible, depending on functional and operational requirements for the site.



file: 3330-t8A

Figure 9-1. Cross-section of the ET-type cover or barrier.

Overlying fine soil must be prevented from entering the coarser underlying media, to maintain the function of both the biobarrier and capillary barrier components. If fine soil fills the coarser media, it can serve as a conduit for both infiltrating water and for plant roots (Keck et al. 1992). Geotextile or a graded filter bed would be placed over the biobarrier to prevent fine soil intrusion.

This cover or barrier was designed to control surface exposures and inhibit biotic intrusion and infiltration for at least 500 to 1,000 years. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. The cover has been constructed at pilot-scale and is therefore considered technically implementable. The relative cost of this cover is moderate. This option is retained for further consideration.

9.5.4.2 Native Soil Cover. This cover type consists of native INEEL soil compacted in lifts and covered with vegetation, gravel, riprap or other media. This design is completely effective in controlling surface exposures, but is not as effective in inhibiting biointrusion as the engineered cover, since maximum rooting depths of native INEEL vegetation including Big Sagebrush can exceed 3 m (10 ft). Sagebrush and potentially other plant species could therefore uptake and mobilize contaminants in the food chain.

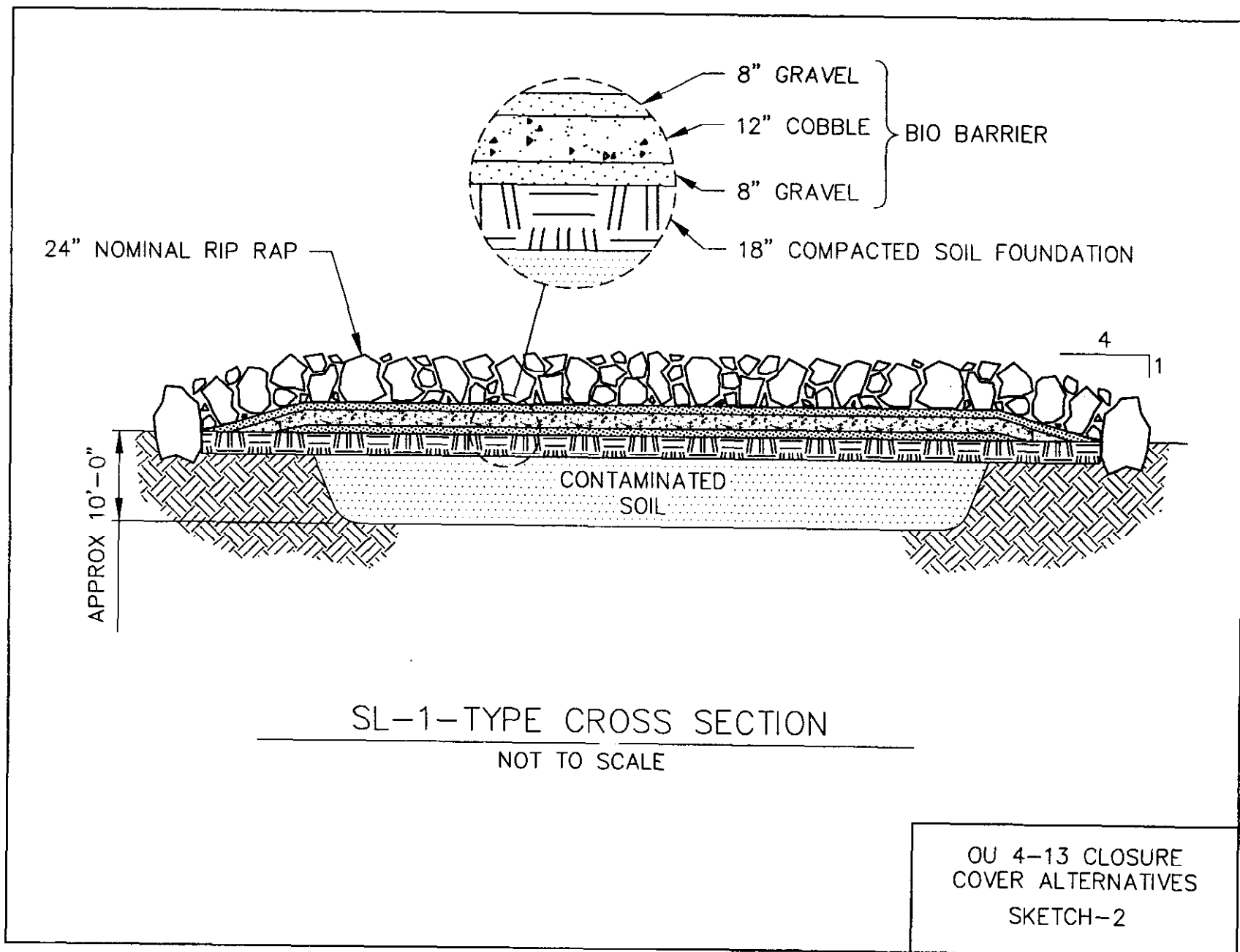
Soil covers are readily implementable and have been previously applied at the INEEL. Impacts to human health and the environment during construction could likely be minimized to allowable levels through administrative and engineering controls. The relative cost of this cover is low to moderate.

This process option also represents backfilling of disposal ponds, consisting of filling contaminated ponds in lifts with clean INEEL native soil, grading, and covering the surface with vegetation or other media. This option is retained for further consideration.

9.5.4.3 SL-1-Type Barrier. The SL-1-type barrier, shown in Figure 9-2, consists of a layer of basalt cobbles approximately 30 cm (12 in.) thick, underlain and overlain by gravel (10 cm [4 in.] thick), with a rock armor surface (0.6 m [2 ft] thick). Overall thickness is approximately 1.2 m (4 ft). This type of barrier was designed to control surface exposures and erosion at uranium mill tailings remedial action (UMTRA) sites for at least 500 years. A biobarrier was added to the SL-1-type design to inhibit biotic intrusion. This barrier is estimated to be effective in reducing human health risks via direct radiation exposure, soil ingestion, and homegrown produce ingestion. Additionally, INEL (1995) determined that this barrier would effectively limit biointrusion, thereby limiting ecological risks.

However, this barrier does not reduce infiltration, does not promote runoff of rainfall and snowmelt, and does not promote lateral drainage of infiltration, which are typical functions of a closure cover. This barrier will likely increase infiltration rates, relative to undisturbed soils, since any rainfall or snowmelt on the barrier rapidly moves through the depth of the very porous rock armor and gravel-cobble layers, beyond the depth of evaporation. Transpiration would not remove water, since no vegetation would be present. This barrier therefore would likely increase risks due to infiltration and leaching of COCs to groundwater, by increasing COC migration through the soil column. Note that GWSCREEN modeling performed for OU 4-13 sites showed no significant groundwater risks resulting from surface infiltration, using a default infiltration rate of 10 cm/yr.

Wind-transported fine soil must be prevented from entering the coarse biobarrier media to maintain the function of the biobarrier. If fine soil fills the gravel and cobble layers, it will serve as a conduit for plant roots (Keck et al. 1992). Geotextiles or a graded filter bed should be placed atop the biobarrier to prevent fine soil intrusion.



file: 3300-t7A

Figure 9-2. Cross-section of the SL-1-type barrier.

This barrier has been built on the INEEL at sites where infiltration and leaching to groundwater is not a concern, and is therefore highly technically and administratively implementable. Impacts to human health and the environment could likely be reduced to allowable levels through administrative and engineering controls. The cost of this cover is low to moderate.

9.5.4.4 RCRA-Type Cover. This type of cover was developed for closing lined RCRA Subtitle C landfills, and consists of three layers including: (1) a low-permeability bottom layer consisting of a geosynthetic flexible membrane overlying a compacted clay layer, (2) a middle drainage layer consisting of sand or geosynthetic drainage net, separated from the overlying layer by a geosynthetic or earthen filter layer, and (3) an upper vegetated layer consisting of soil with grass planted at the surface. The cover is typically built with a 3 to 5% slope at the surface and at layer interfaces, to promote runoff and lateral drainage, and a 4:1 side slopes (EPA 1989). This type of cover is typically 1.8 to 2.4 m (6 to 8 ft) thick.

This design was primarily designed to promote runoff and lateral drainage, and control infiltration, in humid climates. This design is effective in controlling surface exposures and infiltration; however, compacted clay layers have been determined to suffer from desiccation cracking resulting in permeability increases, both during and after construction, particularly in arid regions. Geomembranes may also fail during installation, or due to subsidence, and a design life has not been defined for this type of cover. This design is not highly effective in inhibiting biointrusion, but a biobarrier can be incorporated into the design if required. Constructing the cover is moderately implementable, due to the added complexity of using geosynthetics and compacted clay. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. The cost of this cover is relatively high.

9.5.4.5 Concrete. Concrete is used or planned for use in NRC-regulated low-level waste (LLW) disposal facility elements including disposal vaults, backfill, and closure covers. The primary reason for using concrete in closure covers is to meet NRC requirements for 500 years of post-closure inadvertent intruder protection. While some concrete structures have survived for centuries, concrete is susceptible to damage or attack including:

- Physical damage (including cracking) as a result of subsidence, freeze-thaw action, seismic activity, erosion and abrasion, etc.
- Chemical attack by sulfate, chloride, alkali-aggregate reaction, leaching, acid attack, carbonation, etc. (use of additives may reduce or eliminate some forms of chemical attack)
- Other degradation processes including biodegradation and irradiation (Walton et al. 1990 and 1991).

Concrete with a low water:cement ratio can have a hydraulic conductivity of less than $1\text{E-}12$ cm/second. However, the actual permeability of weathered concrete structures is dominated by cracks, and therefore the permeability will increase over time as weathering occurs (Walton et al. 1991). Sulfur-polymer cements are potentially more resistant to chemical attack by acids and salts, and are also mechanically stronger. Risks of cracking due to landfill subsidence have limited use of concrete for landfill covers.

Concrete would be effective for eliminating direct radiation exposures, soil ingestion, and inhibiting biointrusion. The thickness of the cover could be scaled to the area of the site, shielding requirements, etc. Implementability is higher for smaller than for larger sites. Costs are relatively high.

9.5.5 Disposal

9.5.5.1 RWMC. Disposal of radionuclide-contaminated soil and debris at the RWMC is completely effective in protecting human health and the environment and in meeting RAOs. RCRA-regulated hazardous waste cannot be disposed of at the RWMC; however, LLW resulting from treating mixed waste is allowed for disposal, if the waste is not listed, does not exhibit characteristic hazards and meets all LDR treatment standards. Disposal requirements for contact handled LLW are stated in the INEEL reusable property, recyclable materials, and waste acceptance criteria (RRWAC) (DOE 1998). Characterization requirements include quantitation of specific radionuclides. Soils may be added to fill voids in waste containers, if a plan for this type of disposal is submitted and approved. Bulk disposal of soil is not currently allowed, and the RRWAC contains a list of allowed containers.

This option has been used for prior INEEL CERCLA actions and is therefore readily considered technically and administratively feasible. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. Currently, RWMC operations discourage disposal of low-level radioactively contaminated soils. However, there is no stated INEEL policy preventing the practice, so the option is retained. An estimated 55,813 m³ (73,000 yd³) of disposal capacity remain at the RWMC. Costs are relatively high, if stated disposal costs are applied.

9.5.5.2 INEEL CERCLA Disposal Facility. An INEEL soil repository (the ICDF), projected to be located south of the INTEC, would begin accepting INEEL CERCLA and environmental restoration (ER) soil and debris contaminated with radionuclides and/or other COCs in 2001, and RCRA-hazardous and/or mixed wastes in 2002. The preconceptual design of this facility includes sufficient disposal capacity to accept all such remediation wastes from all INEEL WAGs, including those from WAG 4.

The effectiveness and implementability of this option are uncertain, due to the conceptual status of the project, but the option is retained for further consideration pending a final decision. Projected disposal costs for this facility are much lower than those for the RWMC or offsite low-level radionuclide-contaminated soil and debris landfills.

9.5.5.3 INEEL Landfill Complex. This option could include disposal in the currently operational CFA landfill, or backfilling an existing excavation or disposal pond (e.g., the CFA-04 pond). Soils disposed of in either type of unit would consist primarily of material contaminated with toxic metals at levels above ecological PRGs but which pass the TCLP, and which contain radionuclide concentrations below action levels. The existing CFA landfill could also accept some treated RCRA characteristic wastes (e.g., D004-D011 metal wastes treated to 40 CFR 268.40 standards). The existing CFA landfill is projected to continue to operate at least 10-15 years in the future^b. Soils disposed of there must meet sections of the RRWAC (DOE 1998) applicable to industrial wastes, as well as state and federal regulations.

Characterization requirements would likely be minimal for this alternative, and would likely be met by characterization performed during excavation, as well as process knowledge. The CFA landfill accepts bulk shipments of industrial wastes; therefore, no containerization would be required.

The CFA-04 pond could potentially be backfilled with contaminated soil and capped. This option was previously used for INEEL OU 10-06 radionuclide-contaminated soils, which were consolidated in the Test Reactor Area (TRA) Warm Waste Pond (WWP). The estimated volume to fill the CFA-04 pond

b. M. Wraught, personal communication.

is approximately $3.5\text{E}+04\text{ m}^3$ ($4.6\text{E}+04\text{ yd}^3$), which would be adequate to contain all contamination at OU 4-13, except for the CFA-08 drainfield soils, which are estimated at $5.7\text{E}+04\text{ m}^3$ ($7.4\text{E}+04\text{ yd}^3$).

The effectiveness of this option, if combined with an effective cover on the disposal unit, is considered high. This option is considered technically and administratively implementable. Costs are estimated as low.

9.5.5.4 Offsite Mixed Low-Level Waste Landfill. This option is considered highly effective in protecting human health and the environment and in meeting RAOs. A facility of this type exists approximately 482 km (300 mi) south of the INEEL. The facility is supported by a rail spur, with a railcar rollover, allowing for bulk shipment from the INEEL directly by rail. This facility is permitted to accept low-level radioactive soils, and can treat and dispose of some mixed waste soils.

Prior to disposal at this facility, generators must submit a pre-shipment sample profile record form, then submit a minimum of five, 0.9 kg (2 lb) diverse, representative samples per waste stream. Waste acceptance criteria for this facility include analyses for gamma spectroscopy (natural and man-made isotopes), uranium and thorium isotopic analyses, full TCLP analysis (EPA Method 1311), total metals and total organic, hydrogen sulfide and hydrogen cyanide reactivity, pH, paint filter test for free liquids, additional analyses for individual waste code LDRs, a listed waste evaluation, and a Proctor test (ASTM D-698).

Maximum and average radionuclide activities in OU 4-13 remediation waste were compared to maximum activity allowed under the representative off-site disposal facility's operating permit. All average measured activities are less than allowed levels.

Potential RCRA waste codes for OU 4-13 remediation waste could include D008 and D009. The representative mixed low-level waste (MLLW) treatment, storage, and disposal facility (TSDF) is permitted for treatment and disposal of both of these waste codes (D008 low mercury subcategory only).

Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. The INEEL soils have previously been shipped to this facility for disposal; therefore, this option is considered technically and administratively implementable. Costs for this option are estimated as moderate-high, relative to other disposal options.

9.5.5.5 RCRA TSDF. This option is considered highly effective in protecting human health and the environment and in meeting RAOs for soils contaminated with RCRA-characteristic wastes. The RCRA Subtitle C facilities approximately 482 km (300 mi) from the INEEL at Clive, Utah; and another approximately 1,287 km (800 mi) away at Arlington, Oregon, have previously been used for treatment and disposal of RCRA-contaminated soils.

Prior to disposal at this facility, generators must submit a pre-shipment sample profile record form, then submit representative samples for each waste stream. Waste acceptance criteria include full TCLP analysis (EPA Method 1311), total metal and total organic, hydrogen sulfide and hydrogen cyanide reactivity, pH, paint filter test for free liquids, a listed waste evaluation, and additional analyses for individual waste code LDRs.

Impacts to human health and the environment could likely be reduced to allowable levels through administrative and engineering controls. This process option is therefore considered technically and administratively implementable. Costs for this option are estimated as high, relative to other options.

9.5.5.6 Nevada Test Site. The Nevada Test Site (NTS) is permitted to receive defense low-level and mixed radioactive wastes. The NTS is approximately 970 km (600 mi) southwest of the INEEL and is not serviced directly by rail. Waste transport from the INEEL would be directly by truck, or with transfer from rail cars to trucks near Las Vegas, NV. Currently, the INEEL is not an approved generator for disposal at NTS, and this issue remains unresolved. This option is screened from further consideration as not currently administratively implementable.

9.5.6 Treatment Ex Situ

Ex situ treatment options can be performed on excavated contaminated media, and can be performed onsite or offsite. Several treatment options for INEEL soils and sediments, including physical, chemical, and thermal technologies, have been investigated at bench- and in some cases pilot-scale. The objectives of treatment at CERCLA sites are primarily to reduce the toxicity, mobility, and volume of contaminated media. Toxicity of radionuclides is only reduced by natural radioactive decay, toxicity of toxic metals in most cases cannot be reduced, and organics can be destroyed and toxicity eliminated. Mobility of COCs could be reduced through immobilization in a stable matrix. Volume of contaminated media may also be reduced by ex situ treatment.

Effectiveness of many soil treatment options is very site-specific and depends on contaminants present, soil textural classification, mineralogy, chemistry, and many other factors. Evaluations of effectiveness of treatment options in this FS include technologies evaluated and demonstrated for soils and COCs found at the INEEL, and at the CFA.

Construction requirements may include excavating and transporting contaminated media, constructing above ground process equipment, and other activities. Ex situ treatment options potentially applicable to OU 4-13 sites of concern are discussed below.

9.5.6.1 Physical Separation Using Screening. This technology takes advantage of the typical tendency of radionuclides and heavy metals to be distributed more into soil fines (silts and clays) than into coarse components (coarse sands, gravels, and cobbles). This is often the most effective separation step in a soil washing process. Excavated, contaminated soils can be passed through progressively finer screen sizes, using grizzly shakers or other standard process equipment, to separate fine-grained from coarse-grained fractions. This technology may be used alone or in combination with other treatment technologies to reduce the volume of contaminated soils for disposal.

This technology was tested for Cs-137 separation in treatability studies using TRA WWP sediments and soils (DOE 1995b). Tests determined that this process is effective at separating fine-grained from coarse-grained fractions. However, the effectiveness of screening in reducing the volume of contaminated soils is likely to be limited because Cs-137 in WWP sediments and soils is apparently not sufficiently concentrated in the fine-grained fraction to result in separation of a soil fraction that could be returned to the site (i.e., for which Cs-137 concentrations were less than 16.7 pCi/g, the remedial goal [RG] at the time). About 30% of the total cesium present was in the greater than 8 mesh material (gravel and cobbles), which represented at least 60% by weight of the WWP sample sediments.

This technology has not been tested for separating OU 4-13 toxic metal COCs including Pb, Hg, and Cu from INEEL soils. If metals fractionated significantly into clays and silts, significant volume reduction could be achieved. Effectiveness could only be determined in treatability studies.

Impacts to human health and the environment during operations could likely be reduced to allowable levels through administrative and engineering controls. This option is technically

implementable using standard process equipment. Costs are relatively low. This technology is retained for further consideration.

9.5.6.2 Physical Separation Using Flotation. Flotation separates fine-grained from coarse-grained soils based on their different settling velocities in a water clarifier. This technology is often used in a soil washing process. The soils would be added to a conical tank filled with water, and air introduced into the tank through diffusers or impellers. The bubbles attach to the particulates and the buoyant forces on the combined particle and air bubbles are sufficient to cause fine-grained particles to rise to the surface where they can be recovered by skimmers. Coarse-grained materials are removed from the bottom of the tank.

This technology was tested in treatability studies using TRA WWP sediments and soils. Tests determined that this process is effective at separating fine-grained from coarse-grained fractions. However, the effectiveness of flotation in reducing the volume of contaminated soils was limited, again because Cs-137 distribution in WWP sediments and soils apparently is not sufficiently concentrated in the fine-grained fraction to result in separation of a soil fraction that could be returned to the site (i.e., for which Cs-137 concentrations were less than 16.7 pCi/g, the RG at the time). This technology also produces a secondary liquid waste stream; however, the water may be reusable after treatment.

This technology has not been tested for separating OU 4-13 toxic metal COCs including Pb, Hg, and Cu from INEEL soils. If metals fractionated significantly into clays and silts, significant volume reduction could be achieved. Effectiveness could only be determined in treatability studies.

Impacts to human health and the environment during operations could likely be reduced to allowable levels through administrative and engineering controls. This option is considered moderately technically implementable, due to increased process complexity and requirements for secondary waste handling. Costs are relatively moderate. This technology is retained for further consideration.

9.5.6.3 Physical Separation Using Attrition Scrubbing. Attrition scrubbing consists of mechanical agitation of soil and water mixtures in a mixing tank, to remove contaminants bound to external particle surfaces. This technology was not determined to be effective for cesium removal from WWP sediments and soils (DOE 1995b), because only 18% of the cesium was determined to be associated with phases in and on the sediment particle coatings. The remaining 82% was determined to be associated with the particle internal mineral lattice structure and could be removed only by dissolution of the particle. However, this technology, combined with screening, was estimated to be potentially effective for soils with initial activities within 10 times the RG at the time (i.e., 167 pCi/g). Further treatability studies on representative samples from CFA contaminated soil sites would be required to determine the effectiveness of this technology, alone or in combination with others, to reduce the volume of contaminated soils.

This technology has not been tested for separating OU 4-13 toxic metal COCs including Pb, Hg, and Cu from INEEL soils. Effectiveness could only be determined in treatability studies.

Impacts to human health and the environment during operations could likely be reduced to allowable levels through administrative and engineering controls. This technology also produces a secondary liquid waste stream. Costs are estimated as relatively moderate. The effectiveness of attrition scrubbing for reducing the volume of contaminated materials at OU 4-13 sites is low to uncertain. This option is retained for further consideration.

9.5.6.4 Soil Washing. This technology may include various combinations of physical treatment processes, discussed previously, and chemical processes discussed in this section. This option would consist of physically and chemically extracting contaminants from excavated soils and debris to produce clean soils and concentrated residuals. Clean soils could be returned to the site of concern and concentrated stabilized residuals would likely be landfilled. Extractants could include water, acids, surfactants, brines, carbonates, or other compounds.

Soil washing using water and concentrated nitric acid, in combination with screening, attrition scrubbing and flotation, has previously been tested at bench-scale on TRA WWP sediments with poor results. Although cesium removal efficiency for WWP sediments for the greater than 8 mesh fraction (gravels and cobbles) exceeded 90%, cesium activity in the treated solids still exceeded the 690 pCi/g test treatment goal (INEL 1991a, WINCO 1994, and DOE 1995b). Based on these results, little or no volume reduction of Cs-137 contaminated materials would be achieved using this combination of methods for CFA soils.

Note that the TRA treatability studies were performed on WWP samples. Other native soils and disposal pond sediments at the INEEL may differ in composition and mineralogy.

No soil washing treatability studies have been performed to date using toxic metal-contaminated INEEL soils. The contaminants Pb, Cu, and Hg, as well as radionuclides including U-238 and U-235, have successfully been removed from soils at other sites, including Hanford, using a combination of screening, flotation, and extraction. Much of the volume reduction occurred at the screening step (EPA 1995). Treatability studies would be required to determine effectiveness for Pb, Cu, and Hg in OU 4-13 soils.

Toxicity of the radionuclides and/or toxic metals would not be reduced. This technology would produce large volume secondary waste streams requiring treatment, however in some cases the extractant may be reused, reducing secondary waste volume. The effectiveness of soil washing for reducing risks to human health and the environment and meeting RAOs at OU 4-13 is uncertain. Based on unsuccessful soil washing tests performed on Cs-137-contaminated INEEL soils, and on no prior soil washing tests for toxic metals in INEEL soils, soil washing cannot be determined to significantly improve protection of human health and the environment, or to reduce volumes of contaminated materials, at OU 4-13 sites. Additionally, the relatively small size of the OU 4-13 toxic-metal contaminated sites (CFA-04 and -10) would limit the cost effectiveness of this technology, since significant costs would be incurred for treatability studies and capital equipment. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls.

The implementability of this option is considered low to moderate, based on the requirements for soil- and contaminant-specific treatability studies, the potential complexity of the process, and the potentially large volumes of secondary wastes produced. Costs are considered moderate relative to other ex situ treatment technologies. This option is screened from further consideration on the basis of low cost effectiveness.

9.5.6.5 Physical Separation Using a Segmented Gate System. This technology would apply only to CFA-08, where Cs-137 is present above human health PRGs. The system combines a feed hopper, conveyer belt, real-time gamma spectroscopy and a series of movable gates to separate soils moving on the belt on the basis of activity. Other unit processes including crushing, screening, and sizing may be required to produce relatively uniformly sized feeds. This technology is currently under consideration for the INEEL Pit 9 removal and treatment project to reduce the volume of excavated material requiring treatment prior to final disposal. Materials above and below allowable activities are diverted to different outlets. Soils with radionuclide activities below allowable levels could be returned to

the excavation, while soils with radionuclide activities above allowable levels could be treated further or directly disposed of at an appropriate landfill.

The effectiveness of this technology for OU 4-13 soils and sediments is uncertain and would require field demonstration. This technology has been successfully demonstrated to reduce volumes of radionuclide-contaminated soils at several sites and a field demonstration at the INEEL for separating contaminated soils at the 23 pCi/g Cs-137 PRG is planned for 1999.

This technology does not produce significant secondary waste streams and mainly utilizes conventional material-handling equipment. Gamma radiation detectors may be either germanium or sodium iodide. The gamma monitoring-conveyer and gate system may be combined with other technologies in a treatment train, for example vitrification, to stabilize the soils and sediments containing the highest activities. This option is most applicable to sites where soils have not been disturbed after contamination (i.e., where contaminants have not been homogenized in the soil). These types of sites may include those with wind- and water-deposited contamination. This technology is likely less effective for sites where contaminated soils have been previously consolidated.

Previous uses at Johnson Atoll and at Savannah River claimed high volume reductions; however, effectiveness depends on soil type. Contaminants at Johnson Atoll included particulate radionuclides dispersed in coral carbonate soil. The contaminated soils at Savannah River were encountered during excavations for new construction and ongoing operations. The Savannah River system initially physically screened material greater than approximately 5 cm (2 in.) for separate counting. Some of the reported volume reduction was apparently due to size separation prior to processing through the scanning gate; however, the separation efficiency of sizing alone was not reported. The system operational detection limit was determined to be 2.4 pCi/g. The release criterion was defined as 4 pCi/g; therefore, the system met this requirement. Approximately 1,200 m³ (1,570 yd³) of soil were processed, with a reported volume reduction of 99.3%. Average processing rates were approximately 25 m³/hour (33 yd³/hour). Only one sorter system and four personnel were used. Reported mobilization/demobilization costs are \$25,000 per sorter. Reported processing costs are \$35 to \$60 per yd³ (TMA/Eberline 1995)

Impacts to human health and the environment during operations could likely be reduced to allowable levels through administrative and engineering controls. This technology is considered moderately implementable. Costs are estimated as relatively moderate. This technology is retained for further consideration pending an INEEL field demonstration for Cs-137-contaminated soil.

9.5.6.6 Chemical Stabilization. This option would consist of adding chemical amendments such as Portland cement, polymers, pozzolons, calcium or sodium silicates, or other amendments to excavated soils to produce a stable wasteform. Immobilization of contaminants may occur by formation of an insoluble chemical species, or by microencapsulation in the matrix of the wasteform. This option alone would not significantly reduce risks due to direct radiation exposure that are relative to unstabilized soil. Toxicity of the radionuclides and/or toxic metals would not be reduced; however, availability of COCs and exposure risks via soil ingestion and plant uptake would be reduced. Disposal of the wasteform in a low-level radioactive or mixed waste soil and debris landfill would likely be required. Mobility via leaching and infiltration to groundwater would be reduced. Volume of contaminated materials would increase by up to 200%.

This technology might be used after radionuclide separation using a segmented gate or other system, to produce a stable wasteform for disposal of relatively high concentration solids. However, it is unlikely if any soil fractions from separation processes at CFA would be of high enough activity to require stabilization prior to disposal.

Stabilization in Portland cement, potentially with amendments including calcium silicate, fly ash, or others, would likely meet RCRA LDR treatment standards for OU 4-13 toxic metals including Hg and Pb, based on previous stabilization studies at the INEEL (Gering and Schwendiman 1996) and elsewhere. However, some species of Pb and Hg are difficult to stabilize, and Portland cement stabilization may not provide long-term contaminant immobilization (Mattus and Gilliam 1994). In general, the duration of contaminant isolation for chemical stabilization is undefined, but is significantly less than for vitrification.

Treatability studies would be required to determine effectiveness. Overall, this technology may offer little improvement in effectiveness over excavation and disposal in a secure landfill without treatment, but it is more administratively implementable for RCRA characteristic wastes.

Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. The technical implementability of this option is considered moderate. Extensive handling and mixing of the soils would be required to produce a homogeneous wasteform. However, standard construction and soil handling equipment could be used. Treatability studies would be required to define correct amendments, concentrations, mixing times, etc. Residuals generated would include relatively low volumes of decontamination fluids, PPE, etc. Costs would be low to moderate, which is relative to other ex situ treatment options.

This option is retained for further consideration.

9.5.6.7 Thermal Treatment Using Plasma Torch. This option would consist of vitrifying excavated contaminated soils and debris at high temperatures to produce a stable, glass-like inert wasteform. No reduction in radionuclide activity or toxic metal concentration would occur. Therefore, disposal in a low-level radioactive soil and debris landfill, or a RCRA Subtitle C or D landfill, of the wasteform would likely be required. This option alone would not reduce risks due to direct radiation exposure. Toxicity of the radionuclides and toxic metals would not be reduced. Availability of radionuclides and toxic metals, and exposure risks via soil ingestion and plant uptake, would be reduced. Mobility via leaching and infiltration to groundwater would be reduced. This technology would meet RCRA LDR treatment standards for toxic metal characteristic wastes cited in 40 CFR 268.40. This technology may offer little improvement in effectiveness over excavation and disposal in a secure landfill without treatment, but it is more administratively implementable.

Implementability of this option is considered low due to the technical complexity of the plasma torch process, including the requirement for an air pollution control system. Impacts to human health and the environment during operations could likely be reduced to allowable levels through administrative and engineering controls. Costs would be high.

Effectiveness is estimated as moderate. Costs are relatively high. This option is retained for further consideration.

9.5.6.8 Mercury Retort. This technology applies specifically to mercury-contaminated soils and sediments that fail, or are expected to fail, the RCRA TCLP test. The CFA-04 pond is the only site known at OU 4-13 where high-mercury subcategory RCRA characteristic soils may exist, however, none have been identified to date. Any excavated sediment failing the TCLP would have to be treated prior to disposal outside the AOC, under RCRA land disposal rules. Mercury retorting is specified as a best available technology for RCRA-hazardous nonwastewaters containing greater than 260-mg/kg total inorganic mercury in 40 CFR 268.40. No technology is specified for concentrations less than 260-mg/kg total inorganic mercury, and the TCLP allowable level of 0.20 mg/L is specified instead.

Mercury retorting consists of heating excavated contaminated soil to approximately 538°C (1,000°F) and volatilizing mercury as a vapor. The vapor is subsequently cooled and the liquid mercury recovered. Process equipment may include, but is not limited to, material handlers including a feed conveyer, heating units, heat exchangers, condensers, and air pollution control equipment including a baghouse and granular activated carbon absorbers. Recovered metallic mercury would be recycled.

This process has been used in previous INEEL removal actions to treat onsite CFA and Test Area North (TAN) soils contaminated with mercury in the 10- to 650-mg/kg range to residual concentrations that passed the TCLP. These operations generated large quantities of secondary wastes which included trash, discarded PPE, waste container liners, sanitary wastes, process condensate, scrubber water, and decontamination water. It is estimated that approximately 31 m³ (40 yd³) of secondary solid waste (sludge from the vapor recovery unit); 61 m³ (80 yd³) of contaminated PPE and trash, etc; and 83,000 L (22,000 gal) of secondary liquid wastes were generated while retorting approximately 344 m³ (450 yd³) of contaminated soil from CFA. The volume of secondary waste generated was approximately 50% of the volume of soil processed. These volumes could likely be reduced, based on lessons learned during these efforts.

Technical and administrative implementability of onsite retorting is considered moderate, since it has been implemented previously onsite at the INEEL. The availability of offsite retorting services, or equivalent treatment for high-mercury subcategory soils, is uncertain. No offsite capability was identified, based on responses to a recent LMITCO request for proposals (RFP) published in the Commerce Business Daily (CBD). Of the six responders to the request for offsite MLLW mercury retorting, none were both currently permitted and operating at full-scale. The retorted radioactive soil would likely have to be shipped to another facility after treatment. Implementability of off-INEEL mercury retorting is therefore uncertain. A facility in Tennessee appears the most likely vendor to offer MLLW mercury retorting at the scale required by 2000, and this facility was used as a representative off-INEEL treatment option.

Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. Costs are high. Both on- and off-INEEL mercury retorting are retained for further consideration for CFA-04 sediments and soils that fail the TCLP for mercury, and are contaminated at total Hg concentrations greater than 260 mg/kg.

9.5.7 Treatment In Situ

In situ treatment options are implemented without significant excavation of contaminated media. Construction requirements may include drilling wells, digging trenches, clearing and grubbing surfaces, removing existing structures, constructing aboveground process equipment, and other activities. Maximum remediation depths are assumed to be 3 m (10 ft) bgs, since no groundwater risks exist and all exposure pathways of concern would be addressed by remediating to this depth. In situ treatment options potentially applicable to OU 4-13 sites of concern are discussed below.

9.5.7.1 In Situ Chemical Stabilization Using Mechanical Mixing. This option would consist of using large-diameter augers, equipped with cutting blades and injection systems, to mix soils in situ at depths to at least 3 m (10 ft) bgs with chemical stabilization amendments to produce a stable, leaching-resistant wasteform. The drill unit can be covered with a shroud to control fugitive dust and collect off gas for processing, as required to reduce worker exposures. Augers are typically approximately 1.5 m (5 ft) in diameter and two are used simultaneously (EPA 1997b).

The effectiveness of this option in reducing risks to human health and the environment and in meeting RAOs is estimated as low for radionuclide-contaminated soils, and as moderate to high for toxic metal contaminated soils. This option alone would not eliminate risks to human health via direct radiation exposure. However, it may potentially reduce or eliminate risks due to homegrown produce ingestion and soil ingestion at OU 4-13 sites. Environmental risks would be reduced or eliminated by eliminating contaminant transport and/or exposure pathways. Toxicity of the COCs would not be reduced. Volume of contaminated materials would likely increase 30 to 50%, due to addition of amendments, which would raise the surface grade of the stabilized area several feet. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls.

Implementability of this option is moderate. Various methods of in situ chemical stabilization have been previously demonstrated at the INEEL, both for contaminated soils and landfilled waste (DOE 1995b). Costs are considered relatively moderate (\$20 to \$40 per yd³ in 1997 dollars [EPA 1997b]).

Soil mixing is not cost-effective at sites where only surficial contamination occurs (e.g., CFA-10); or where contamination is relatively shallow (e.g., CFA-04), or where rock occurs at shallow depths within the melt zone (e.g., CFA-04). Soil mixing would be most technically implementable at CFA-08, where contamination extends to at least 3 m (10 ft) bgs. However, direct radiation exposure could still occur from the grouted product. Additionally, Cs-137 at CFA-08 will decay to unrestricted release levels (2.3 pCi/g) in 189 years, which results in overall low cost-effectiveness for soil mixing at this site. This option is screened from further consideration on the basis of low technical implementability and high cost.

9.5.7.2 In Situ Soil Washing. This process uses infiltration galleries or injection wells to advect extraction fluids through contaminated soils in situ. Downgradient wells recover the fluids for separation of the contaminants and reuse. Extraction fluids may include unamended water, acids or other oxidizers, surfactants, and others. This option would reduce or eliminate risks to human health and the environment from OU 4-13 sites by chemically removing contaminants for subsequent stabilization and disposal elsewhere. Toxicity of the COCs would not be reduced. Mobility of residual COCs would not be reduced without subsequent treatment and stabilization. Volume of contaminated materials might potentially be reduced, if effective.

As for ex situ soil washing, the effectiveness and technical implementability of this option is considered low. Soil washing, in combination with physical separation, has previously been tested at bench-scale for radionuclides including Sr-90 and Cs-137 on the INEEL TRA WWP sediments with poor results (INEL 1991). No soil washing treatability studies have been performed to date using toxic metal-contaminated INEEL soils. Treatability studies would be required to determine effectiveness for Pb, Cu, and Hg in OU 4-13 soils.

In situ soil washing is more technically complex than ex situ soil washing, due to the requirement for hydraulic control over the extractant fluid; and is likely less effective due to the difficulty of uniformly contacting the extractant fluid with contaminated media. Costs are considered moderate relative to other in situ treatment technologies. Impacts to human health and the environment would be minimal.

This option is screened from further consideration due to low technical implementability and low effectiveness.

9.5.7.3 In Situ Vitrification. In situ vitrification can potentially vitrify contaminated soils at depth to create a stable, glass-like mass. This technology is most commonly applied to soils contaminated to

depths of at least 3 m (10 ft) bgs. The technology in situ vitrification (ISV) was developed by Batelle Pacific Northwest Laboratory, and is marketed exclusively by the Geosafe Corp., Richland, WA. A containment shroud is erected over the melting site and is maintained under negative pressure. The outlet of the shroud is connected to an off-gas treatment system consisting of a blower, and a combination of quenchers, scrubbers, mist eliminators, heaters, filters, and activated carbon adsorption specific to the site characteristics and contaminants.

Graphite electrodes are placed vertically in soil and large electrical currents applied to produce resistance heating. Power is supplied at the top of the soil initially. Flaked graphite and glass frit are placed on the soil to increase the electrical conductivity sufficiently to initiate melting. When melting begins, the electrodes are lowered 2.5 to 5 cm (1 to 2 in.) per hour, until the entire soil mass bounded by the electrodes is heated to 871 to 1,093°C (1,600 to 2,000°F) and melted. After cooling, the resulting wasteform is a leaching resistant glass-like form similar to obsidian. The process equipment is typically transported on three trailers, and is powered by utility power or a diesel generator. Typical power requirements are 800 to 1,000 kWh per ton of treated soil (EPA 1997b).

Volatile metals including mercury are volatilized during melting and captured by the off-gas treatment system, while less volatile metals including lead and arsenic tend to remain in the glass phase. Cesium may remain in the melt or volatilize, depending on the depth and time of the melting. The fate of silver is unknown. Volatile organics (VOCs) are vaporized or pyrolyzed by ISV. Vaporized VOCs that migrate to the surface are either burned in the hood covering the treatment area, or are treated in the off-gas treatment system (EPA 1994).

Site-specific considerations limiting technical implementability of ISV include: (1) void volume within a melt greater than 10%, (2) rubble greater than 20% by weight, and (3) combustible (organic) material greater than 5 to 10%. Soils with organic contents greater than 10% can reportedly be processed using lower melting rates and a larger scale off-gas treatment system. Recommended depth range of contamination for cost-effective implementation is 1.5 to 6 m (5 to 20 ft) bgs (EPA 1998).

The effectiveness of this option in reducing risks to human health and the environment and in meeting RAOs depends on the contaminants and exposure pathways of concern. This option alone would not significantly reduce risks to human health via direct radiation exposure, since most of the Cs-137 would remain in place. Immobilizing toxic metals in the glassy matrix would provide highly effective long-term containment, and would eliminate risks due to homegrown produce ingestion and soil ingestion for geologic time periods. Environmental risks would also be reduced or eliminated by eliminating exposure pathways. Mercury would primarily be volatilized, captured by the air treatment system, retorted to produce elemental mercury and shipped offsite for recycling, essentially eliminating risks due to mercury from the site. Residual amounts of mercury might remain in the glass at depth, but would be immobilized. Institutional controls may be required for long-term management of contaminants remaining at the site.

Toxicity of the radionuclides and toxic metals remaining in the melt would not be reduced; however, organics would be volatilized and captured, or destroyed by this method. Volume of contaminated soils could be reduced by as much as 20 to 45%, and the cooled melt surface could subside as much as 0.6 to 1.5 m (2 to 5 ft), relative to ground surface. Impacts to human health and the environment during implementation could likely be minimized to allowable levels through administrative and engineering controls.

Residuals produced by this process include metal vapor, organics, and solids captured on activated carbon, filters, or in scrubber solutions by the air pollution control system. Treatment media used to

capture mercury could include a permanganate scrubber solution, or sulfur-impregnated carbon. Either type of media could be retorted onsite by the subcontractor to recover nonradioactive mercury for recycling, reducing the volumes of residual treatment media for disposal.

Implementability of this option is moderate to uncertain. Technical implementability is very site-specific. Melting rates of 5 to 6 m³/hour (6 to 8 yd³/hour) are reported (EPA 1997b). Costs are relatively high.

The ISV is not cost-effective at sites where only surficial contamination occurs (e.g., CFA-10); or where contamination is relatively shallow (e.g., CFA-04); or where rock occurs at shallow depths within the melt zone (e.g., CFA-04). The ISV would be most technically implementable at CFA-08, where contamination extends to at least 3 m (10 ft) bgs. However, Cs-137 at CFA-08 will decay to unrestricted release levels (2.3 pCi/g) in 189 years, which results in low cost-effectiveness for ISV at this site. This option is screened from further consideration on the basis of low technical implementability and high cost.

9.5.7.4 Phytoremediation.

Description. Phytoremediation is an innovative and emerging technology that utilizes surface vegetation to uptake toxic metals and radionuclides through roots and to degrade organic compounds in situ. Vegetation types may include grasses, vegetables, shrubs, trees, or other species. Metals incorporated in biomass may be recovered by harvesting the vegetation and incinerating the biomass. Incinerator residuals would require stabilization and disposal in a low-level radioactive waste, RCRA, or mixed-waste landfill.

Phytoremediation is most applicable for contaminants distributed within the rooting zone, typically 1 m (3 ft) maximum depth (EPA 1997). Parameters affecting application of this process include soil type and characteristics, contaminant type and chemical species, climate and others. Immobile precipitated contaminant species are not typically treatable by this method, without soil amendments. Soil amendments have included chelating agents like EDTA (Chaney et al. 1997), which can mobilize lead; and ammonium nitrate (DOE 1997b), which displaces exchangeable cations like Cs-137. Treatability studies are typically required to implement this technology successfully (EPA 1997).

Arthur (1982) observed radionuclide uptake in INEEL vegetation including Russian thistle, crested wheatgrass, and gray rabbitbrush growing on waste disposal sites, but did not quantitate uptake rates from soil. A number of plant species were evaluated for remediating low levels of Cs-137 and Sr-90 in soil at Brookhaven National Laboratory (BNL) (DOE 1997b). Hydroponic screening studies identified Reed canary grass (*Phalaris arundinacea*), Indian mustard (*Brassica juncea*), tepary bean (*Phaseolus acutifolius*), and cabbage (*Brassica oleracea*) as potentially hyperaccumulators of Cs-137. Subsequent studies in pots evaluated Cs-137 uptake from soil by these species. This study also evaluated soil amendments for releasing cesium sorbed to clay minerals, identified as a major impediment to phytoremediation of cesium. The most successful treatment consisted of amending soil with ammonium nitrate to promote release of cesium, allowing for subsequent uptake by cabbage. Cabbage grown in Cs-137-contaminated soils amended with 80-mole ammonium nitrate per kg soil showed bioaccumulation factors of approximately three, measured as activity of Cs-137 in dry shoot mass/Cs-137 in dry soil mass. This study indicated that reduction of initial Cs-137 soil activities of approximately 400 pCi/g to less than 100 pCi/g (75% activity reduction) using cabbage would take at least 15 years. The study also concluded that bioaccumulation ratios would decrease as activities decreased, making removal to lower activities unlikely in a reasonable time period.

Entry and Watrud (1998) determined that Alamo Switchgrass (*Panicum virginatum*) removed up to 44 and 36% of Sr-90 and Cs-137, respectively, from relatively shallow soil depths in pan (7 cm [3 in.] deep) and tube (30 cm [12 in.] deep) studies. Removal rates increased with increased soil radionuclide concentrations, and declined with successive plant harvests.

Argonne National Laboratory West (ANL-W) will begin a field demonstration in 1998. If successful, this technology would be applied to 15,000 m³ (19,400 yd³) of soils contaminated primarily with Cs-137 in the upper one foot of the soil column at ANL-W. After accumulating radionuclides, the vegetation would be harvested, sampled, and shipped to an incinerator on the INEEL for volume reduction. The resulting ash would then be sampled and sent to a permitted disposal facility.

A 1995 Argonne National Laboratory-East (ANL-E) study (DOE 1996) determined that *Phragmites australis*, a native plant determined to be tolerant of high toxic metal content soils, was able to uptake Pb but would not be able to reduce soil Pb initial concentrations ranging from 500 mg/kg to a 300 mg/kg release level within a reasonable time (20 years). Chemical species of lead present is likely very important in uptake rates; relatively soluble lead carbonate is reportedly accumulated by *Festuca rubra* (a grass), while elemental lead is likely not. Significant plant uptake of lead has not been demonstrated, but research utilizing soil amendments to increase uptake rates is reportedly underway (EPA 1997).

Effectiveness of this technology for OU 4-13 sites of concern is uncertain, because no treatability studies have been done to date for mercury, lead or Cs-137 in WAG 4 soils. However, results of previous studies are used in this section to provide a screening-level evaluation of effectiveness and technical implementability.

The maximum measured Cs-137 activity at CFA-08 is 180 pCi/g. Reduction to the PRG of 23.3 pCi/g would require an 87% activity reduction. Depth of contamination requiring remediation is 3 m (10 ft) bgs, which exceeds the 1 m (3 ft) upper limit of contaminant depths suggested by EPA (1997) by nearly a factor of three. Not all contamination is dispersed in soil; feeder lines and drain tiles still contain contaminated sludge, which would not be amenable to phytoremediation. Time to reach PRGs is unknown, because no treatability studies have been performed to date on WAG 4 soils and COCs. However, using the results of the DOE (1997b) study cited previously, over 15 years (minimum) would be required to attain the required Cs-137 activity reduction in the shallow treatment zone, using the best plant species and soil amendments identified in the study. Soil contamination at depths exceeding the rooting depth of the cabbage used would not be remediated, nor would sludges in feeder lines and drain tiles.

The maximum measured Hg concentration at CFA-04 is 439 mg/kg. Reduction to the ecological risk PRG of 0.74 mg/kg would require a 99.8% concentration reduction, which is likely unattainable. The depth of contamination is 0 to 0.9 m (0 to 3 ft) below the bottom of the pond (3 m [10 ft] bgs), which is potentially within the 1 m (3 ft) upper limit of contaminant depths suggested by EPA (1997). Genetically engineered plants have been developed specifically to uptake mercury from soil and groundwater (Flathman et al. 1998). However, mercury is not stored in biomass but is transpired and released to the atmosphere (i.e., volatilized). This "treatment" would not reduce toxicity (except through dilution), mobility or volume, and would merely dilute the mercury by dispersing it in air for eventual re-deposition to soil.

Technical implementability of this technology for WAG 4 sites is low to uncertain. The relatively short growing season of the INEELs sagebrush steppe environment constrains both species selection and biomass production. If nonarid climate vegetation species were used, which would likely be required to maximize biomass production, supplemental irrigation would likely be required, which could potentially

flush mobile contaminants to depths greater than recoverable. This would also be a concern if supplemental soil amendments designed to increase uptake rates were used. Costs of this technology are estimated as low, relative to other in situ treatment technologies. Impacts to human health environment would be minimal. However, contaminants taken up by plants could be mobilized in the food chain during the treatment period, threatening environmental receptors.

Phytoremediation is screened from further consideration due to technical impracticability and lack of demonstrated effectiveness for INEEL soils and COCs.

9.5.8 Summary

Environmental monitoring process options retained include only soil monitoring. Institutional control actions include fences, deed restrictions, cap integrity monitoring and maintenance, and surface water diversion. The representative excavation technologies are standard equipment including backhoes and dozers. Robotics were rejected as not cost-effective. Field screening using gamma monitors and XRF would be used to the extent feasible to minimize the amount of uncontaminated soil removed.

Containment options retained include the SL-1-type and ET-type engineered barriers, the native soil cover, the RCRA-type cover and concrete.

Disposal options retained include the INEEL RWMC, the ICDF, an offsite MLLW landfill, an INEEL nonhazardous, nonradioactive disposal unit (e.g., the existing CFA landfill or the CFA-04 pond), and an offsite RCRA TSDF. The ICDF is retained pending a final decision on this project. The NTS was rejected from further consideration, since the INEEL is not currently an approved generator.

Ex situ treatment options for excavated radionuclide and metal-contaminated soils were evaluated based on their ability to reduce the overall toxicity, mobility and volume of contaminated soils at OU 4-13 sites. Technologies retained include segmented gate radioactive soil separation, chemical stabilization, plasma torch vitrification, and mercury retorting of mercury-contaminated soils.

Soil washing for removing Cs-137 was rejected on the basis of no demonstrated effectiveness for INEEL soils, as were flotation and attrition scrubbing. Soil washing for removing Pb, Cu and Hg was rejected, on the basis of low cost effectiveness. Screening was retained as a potential pretreatment step for other options.

No in situ treatment options were retained, due to low technical implementability, low effectiveness and high cost.

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10. DEVELOPMENT OF ALTERNATIVES

Remedial alternatives are developed in this section. Alternatives were developed by selecting a representative process option for each GRA and technology type from those retained after screening in Section 9. Selected process options were then combined to formulate a range of remedial alternatives potentially capable of meeting RAOs, given the contaminant types and exposure pathways of concern specific to each site. Technology types comprising alternatives for each site are shown in Table 10-1.

10.1 Alternative 1: No Action with Monitoring

This alternative could be applied to any OU 4-13 site of concern. Formulation of a No Action with Monitoring alternative (Alternative 1) is required by the National Contingency Plan (NCP) [40 CFR 300.430 (e)(6)] and guidance for conducting feasibility studies under CERCLA (EPA 1988). The No Action with Monitoring alternative serves as the baseline for evaluating other remedial action alternatives. This alternative can include environmental monitoring (groundwater, air, and soil) for up to 100 years after low level waste disposal site closure, but does not include institutional controls to reduce potential exposure pathways, such as fencing or deed restrictions (EPA 1988). Five-year reviews are included, as required under the NCP.

10.2 Alternative 2: Institutional Control

An Institutional Control alternative (Alternative 2) was developed comprised of institutional controls implemented by the INEEL and assumed to remain in effect for up to 100 years; and deed restrictions that would limit uses of property, if transferred from government control to private ownership, which could remain effective indefinitely. This alternative could be applied to any OU 4-13 site of concern. Management practices currently implemented at OU 4-13 contaminated soil sites would continue and would additionally include site inspection and monitoring. Actions under this alternative would implement access restrictions during the institutional control period using fences and signs, radiation surveys at sites where radionuclides remain in place, and routine site inspection and monitoring for animal burrows, erosion, etc. Surface water diversion is included to minimize the potential for surface water accumulating at the site, and would include inspecting and maintaining drainage systems.

If the property were ever transferred to non-government ownership, the U.S. Government would create a deed for the new property owner that would include information required under Section 120(h) of CERCLA. The deed shall include notification disclosing former waste management and disposal activities that occurred on the site; and shall, in perpetuity, limit property uses through restrictive covenants or easements to those determined to not result in human health risks above allowable levels.

Any remedial alternative relying on institutional controls requires an Institutional Control Plan, prepared and submitted as an enforceable provision of the ROD (EPA 1998). The Plan must specify what must be done to impose and maintain the required land use restrictions and/or other controls. Institutional controls would be reviewed annually for the first 5 years following site closure. The need for further institutional controls would be evaluated and determined by the agencies during subsequent 5-year reviews.

Table 10-1. Remedial alternatives for OU 4-13 contaminated soil sites.

GRA/Technology Type/ Process Options	Remedial Alternatives				
	1 No Action With Monitoring	2 Institutional Control	3a Excavate/ Treat/ICDF Disposal	3b Excavate/Treat/ Off-INEEL Disposal	4 Containment in Place- ET-Type Cover
Monitoring					
Soil monitoring	X	X			X
Institutional Controls/Access Restrictions					
Fences		X			X
Deed restrictions		X			X
Institutional controls/ maintenance		X			X
Cap integrity monitoring and maintenance					X
Surface water diversions		X			X
Excavation					
Backhoes and dozers			X	X	
Containment/ Capping					
ET-type barrier					X
SL-1-type barrier					
RCRA-type barrier					
Native soil barrier					
Native soil backfill			X	X	
Concrete cover					
Disposal/ Landfilling					
RWMC					
ICDF			X		
Backfill existing disposal pond					
Offsite mixed waste TSDF				X	

Table 10-1. (Continued).

GRA/Technology Type/ Process Options	Remedial Alternatives				
	1 No Action With Monitoring	2 Institutional Control	3a Excavate/ Treat/ICDF Disposal	3b Excavate/Treat/ Off-INEEL Disposal	4 Containment in Place- ET-Type Cover
In Situ Treatment					
In situ chemical stabilization					
ISV					
Phytoremediation					
Ex Situ Treatment					
Segmented gate			CFA-08, only (on INEEL)	CFA-08, only (on INEEL)	
Stabilization			CFA-04, -10 only (on-INEEL)	CFA-04, -10 only (off- INEEL)	
Plasma torch					
Thermal desorption					
Mercury retort					

10.3 Alternatives 3a and 3b: Removal, Treatment, and Onsite Disposal; and Removal, Treatment, and Offsite Disposal

Remedial alternatives incorporating treatment were developed, to meet EPA expectations that treatment be used "...to address principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile compounds" (40 CFR 300.430). Treatment would also be required for soils with RCRA hazardous characteristics, present at CFA-04 and -10, which were removed from the AOC.

Treatment alternatives were developed to allow risk managers to determine their cost-effectiveness and practicability, relative to other alternatives. These alternatives could be applied to any OU 4-13 site, however the nature and extent of contamination are sufficiently different that details specific for each site are discussed below.

10.3.1 Alternative 3a: Removal and Onsite Treatment and Disposal

10.3.1.1 CFA-04. The CFA-04 disposal pond is estimated to contain a relatively small volume (609 m³ [796 yd³], 8.7% of the total volume of soil contaminated above PRGs at the site) of RCRA hazardous wastes (D009). This alternative would consist of the following actions:

- Characterizing soils and excavating all soil and sediments from the pond exceeding human health and ecological risk PRGs, to a depth of at least 0.9 m (3.0 ft) below the bottom of the pond (3 m [10 ft] bgs); basalt at depths less than 0.9 m (3.0 ft) bgs would not be excavated
- Transporting soils contaminated above PRGs to the ICDF
- Stabilization in Portland cement and disposal of RCRA-hazardous soils at the ICDF
- Direct disposal of non-RCRA-hazardous soils at the ICDF
- Verification sampling to ensure that no contamination exceeding PRGs remained
- Returning soils contaminated at less than PRGs to the excavation
- Backfilling the excavation with clean native soil, with a final sloping finish grade to divert water, and revegetating the site
- Implementing 5-year reviews and deed restrictions, if contamination above PRGs remained.

Other treatment or disposal process options might potentially be selected in the ROD and/or during remedial design. No long-term monitoring would be required for the CFA-04 pond after completing the remediation. Backhoes and dozers were assumed to be used for excavating contaminated soil and sediments.

10.3.1.2 CFA-08. The only COC for CFA-08 is Cs-137. The representative process option for radionuclide-contaminated soils is segmented gate separation (SGS). A pilot-scale treatability study will be performed in 1999 to assess the effectiveness and technical feasibility of SGS treatment of Cs-137-contaminated INEEL soils. If SGS treatment is not determined to be cost effective or technically feasible,

then treatment would be eliminated from this alternative for CFA-08 and soils would be disposed of directly at the ICDF. This alternative would consist of the following actions:

- Characterizing soils and excavating all soil and sediments from the drainfield exceeding human health risk PRGs, to a depth of at least 3 m (10 ft) bgs; basalt at depths less than 3 m (10 ft) bgs would not be excavated.
- Sludges remaining in drainfield feeder lines would be allowed to drain into soil during excavation. Drainfield tiles and other debris would then be excavated, crushed and screened to reduce the size of materials to less than two inches nominal diameter.
- Processing soils and crushed debris through the SGS to separate out material contaminated with Cs-137 at activities above the PRG.
- Transporting all soils above PRGs to the ICDF.
- Verification sampling to ensure that no contamination exceeding PRGs remained.
- Returning soils contaminated at less than PRGs to the excavation.
- Backfilling the excavation with clean native soil, with a final sloping finish grade to divert water, and revegetating the site.
- Implementing 5-year reviews and deed restrictions, if contamination above PRGs remained.

If the SGS pilot-scale treatability study determines that the treatment is not cost-effective, then treatment would not be implemented and soils above PRGs would be disposed of directly at the ICDF.

10.3.1.3 CFA-10. All soils at CFA-10 were assumed to be RCRA characteristic wastes (D008 for Pb) for cost estimating purposes for this alternative. Contamination is assumed to extend to 0.15 m (0.5 ft) bgs. This alternative would consist of the following actions:

- Characterizing soils and excavating all soil exceeding human health and ecological risk PRGs
- Transporting soils contaminated above PRGs to the ICDF
- Stabilization in Portland cement and disposal of RCRA-hazardous soils at the ICDF
- Direct disposal of non-RCRA-hazardous soils at the ICDF
- Verification sampling to ensure that no contamination exceeding PRGs remained
- Returning soils contaminated at less than PRGs to the excavation
- Backfilling the excavation with clean native soil, with a final sloping finish grade to divert water, and revegetating the site.

Other treatment or disposal process options might potentially be selected in the ROD and/or during remedial design. No long-term monitoring would be required after completing the remediation. Backhoes and dozers were assumed to be used for excavating contaminated soil and sediments.

10.3.2 Alternative 3b: Removal, Treatment and Disposal Off-INEEL

10.3.2.1 CFA-04. This alternative would consist of the actions described in Section 10.3.1.1 for Alternative 3a for this site, except that soils would be transported to, and treated and disposed of at an off-INEEL MLLW TSDF.

Other treatment or disposal process options might potentially be selected in the ROD and/or during remedial design. No long-term monitoring or institutional control would be required for the CFA-04 pond after completing the remediation. Backhoes and dozers are assumed to be used for excavating contaminated soil and sediments.

10.3.2.2 CFA-08. This alternative would consist of the actions listed in Section 10.3.1.2 for Alternative 3a for this site, except that all soils contaminated at levels above PRGs would be transported to an off-INEEL LLW landfill for disposal.

If the SGS pilot-scale treatability study determines that the treatment is not cost-effective, then treatment would not be implemented and soils above PRGs would be disposed of directly at the off-INEEL disposal facility.

10.3.2.3 CFA-10. This alternative would consist of the actions listed in Section 10.3.1.3 for Alternative 3a for this site, except that all soils above PRGs would be transported to an off-INEEL RCRA Subtitle C landfill. Soils determined to be RCRA-hazardous would be stabilized prior to disposal, while nonhazardous soils contaminated above PRGs would be disposed of directly at the off-INEEL facility. Soils contaminated at levels below PRGs would be returned to the excavation. Institutional controls were assumed to not be required, since all contamination would be removed.

10.4 Alternative 4: Containment and Institutional Controls

This alternative could be applied to any OU 4-13 site. The alternatives developed for containing contaminants at OU 4-13 soil release sites are based on capping technologies designed to meet RAOs by eliminating exposure pathways identified in the baseline risk assessment (BRA). Human health risks due to Cs-137 exposure at CFA-08 will decline to unrestricted release levels within 189 years through natural radioactive decay. However, human health and ecological risks due to toxic metals at CFA-04 and -10 will not. Containment technologies must be designed to maintain integrity for the period of time that unacceptable cumulative exposure risks will be present. The functional life of a particular cover design depends on how long potential failure mechanisms including erosion, subsidence, geosynthetic failure, infiltration, biotic and human intrusion, and others can be delayed.

The containment option must also meet RCRA 40 CFR 264.310 (a)(1-5), considered relevant and appropriate for CFA-04 and -10, where RCRA hazardous wastes are present. These include functional requirements that the cap:

- Provide long-term minimization of migration of liquids through the closed landfill
- Function with minimum maintenance

- Promote drainage and minimize erosion or abrasion of the cover
- Accommodate settling and subsidence so that the cover's integrity is maintained
- Have permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

The ET-type cap was determined to best meet functional requirements and was selected as the representative capping process option for Alternative 4 for all sites. The preconceptual design identified for the containment alternative in this FS would be developed during remedial design and modified as needed to meet defined functional and operational requirements, with the concurrence of regulatory agencies. Design and construction details for Alternative 4 specific to each OU 4-13 site of concern are discussed below.

Constructing the ET-type of cover at CFA-04 would require backfilling the pond with clean native soil to bring the level to grade, with compaction. A foundation of approximately 0.46 m (18 in.) of compacted soil would next be placed in lifts. The foundation and all overlying layers would be sloped 2 to 4% from the centerline of the cap. The gravel-cobble biobarrier/capillary barrier would be constructed over the foundation layer next, with approximately 0.15 m (0.5 ft) of gravel overlying 0.76 m (2.5 ft) of cobbles. A geotextile layer, or a graded filter bed, would be placed on top of the upper gravel layer to prevent overlying soil from entering the gravel. Successive lifts of compacted native soil would be added next, with a total thickness of 1.25 m (4.1 ft). A surface layer of 0.15 m (0.5 ft) of soil with a rock mulch and added fertilizer for establishing vegetation and resisting erosion would be graded and completed with a 2 to 4% slope. The surface would be vegetated with a mix of grasses found to be readily established and sustained on disturbed soils on the INEEL (DOE 1989).

Constructing this type of cover at CFA-08 and -10 would first require clearing and grubbing the site, then constructing the foundation with successive lifts of native soil applied with compaction between lifts. Minimum cover thickness would be approximately 2.8 m (9 ft) at the perimeter of the contaminated area, and thicker at the centerline due to the sloped layers. For example, at CFA-08 with dimensions of approximately 61 × 305 m (200 × 1,000 ft), the centerline thickness would be at least 4.0 m (13 ft). The surface would be graded to divert water, rock mulch added and the finished surface vegetated with appropriate grasses to minimize erosion and promote evapotranspiration.

Institutional controls, as for Alternative 2, would be implemented. Additionally, the cap would be maintained during the 100-year institutional control period.

10.5 References

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